NEW ENGLAND WATER WORKS ASSOCIATION.

ORGANIZED 1882.

Vol. VIII December, 1893. No. 2.

This Association, as a Body, is not responsible for the statements or opinions of any of its members.

FALL EXCURSION.

September 13th, 1893.

The fall meeting of this Association was held at Plymouth, Mass., on Wednesday, September 13th, 1893. The day was bright and clear, the temperature just right for bodily comfort, the picturesque scenery of Plymouth was displayed to its best advantage, and the hospitality of our Plymouth friends was bountiful. All present expressed themselves as having participated in one of the most delightful programmes ever given by this Association.

The members were met at the depot, on arrival of the trains shortly after 10 o'clock, by the members of the Plymouth Water Board. Barges were then taken and the first stop was made at the national monument to the forefathers. Thence a visit was made to Pilgrim hall and some time was spent in looking over the interesting relics of the Pilgrims. The next stop was made at Plymouth rock and Cole's hill. Explanatory statements, both historical and otherwise, were carefully made to the party at all of the above mentioned places by Charles S. Davis, Esq. The drive was then extended to the Pumping Station of the Plymouth Water Works, where the party was most hospitably received and cared for by Superintendent R. W. Bagnell. The neatness of the buildings and surroundings are worthy of special mention.

The company then proceeded to Hotel Pilgrim, located on high land about three miles south of Plymouth. A delightful sea view is afforded from the broad piazza of the hotel, and the air was so very clear that Race Point lighthouse on Cape Cod, twenty miles distant, could be discerned. At the close of the dinner and before the party had left the dining hall a vote of thanks was tendered the Water Commissioners and other citizens of Plymouth for the courteous attention shown the members of the New England Water Works Association and their friends. At 3 o'clock the party left the hotel to return to their various homes.

The following is a list of those who composed the party:

ACTIVE MEMBERS.

Richard W. Bagnell, Superintendent, Plymouth, Mass.; Lewis M. Bancroft, Superintendent, Reading, Mass.; Nathan B. Bickford, Superintendent W. W. O. C. R. R., Boston, Mass.; George Bowers, City Engineer, Lowell, Mass.; Dexter Brackett, Assistant Engineer, Boston, Mass.; John C. Chase, Superintendent, Wilmington, N. C.; Freeman C. Coffin, Civil Engineer, Boston, Mass.; R. C. P. Coggeshall, Superintendent, New Bedford, Mass; Lucas Cushing, Assistant Superintendent. Boston, Mass.; Edwin Darling, Superintendent, Pawtucket, R. I.; Francis W. Dean, Mechanical Engineer, Boston, Mass.; Frank L. Fuller, C. E., Boston, Mass.; Albert S. Glover, Boston, Mass.; W. J. Goldthwait, Marblehead, Mass.; Frederick W. Gow, Superintendent, Medford, Mass.; Frank E. Hall, Superintendent, Quincy, Mass.; James H. Higgins, Superintendent Meter Department, Providence, R. I.; David B. Kempton, Commissioner, New Bedford, Mass.; Patrick Kieran, Fall River, Mass.; Horace Kingman, Superintendent, Brockton, Mass.; A. E. Martin, Superintendent, South Framinghom, Mass.; Edward C. Nichols, Commissioner, Reading, Mass.; Albert F. Noyes, Asst. Engineer State Board of Health, Boston, Mass.; George J. Ries, Superintendent, Weymouth Centre, Mass.; Henry W. Rogers, Superintendent, Haverhill, Mass., A. H. Salisbury, Superintendent, Lawrence, Mass.; M. M. Tidd, Hydraulic Engineer, Boston, Mass.; D. N. Tower, Superintendent, Cohassett, Mass.; W. H. Vaughn, Superintendent, Wellesley Hills, Mass.; A. H. Brodrick, Chadwick Lead Works, Boston, Mass.; F. H. Hayes, Dean Steam Pump Co., Boston, Mass.; Henry F. Jenks, Pawtucket, R. I.; N. F. Ryder, Middleboro, Mass.; J. C. Otis, Union Water Meter Co., Worcester, Mass.; George C. Duane, Portland Stoneware Co., Boston, Mass.; E. H. Rice, Walworth Manufacturing Co., Boston, Mass.; H. A. Gorham, The George Woodman Co., Boston, Mass.

GUESTS.

Mr. and Mrs. A. B. Alden, Middleboro, Mass,. John Alden, Middleboro, Mass.; Mr. and Mrs. Frank M. Ashley, New Bedford, Mass.; Mrs. Lewis M. Bancroft, Reading, Mass.; Mr. and Mrs. H. P. Bailey, Plymouth, Mass.; Mrs. Joseph E. Beals, Middleboro, Mass.; Mrs. Geo. Bowers, Lowell, Mass.; Mrs. Dexter Brackett, Boston, Mass.; H.D. Brackett, Boston, Mass.; Samuel Bradford, Water Commissioner, Plymouth, Mass.; Mrs. Freeman C. Coffin, Boston, Mass.; Mrs. R. C. P. Coggeshall, New Bedford, Mass.; Mrs. Edwin Darling, Pawtucket, R. I.; Mrs. F. W. Dean, Boston, Mass.; Charles G. Davis, Plymouth, Mass.; Mr. and Mrs. Charles S. Davis, Plymouth, Mass.; William T. Davis, Plymouth, Mass.; Miss Davis, Plymouth, Mass.; Mrs. F. L. Fuller, Boston, Mass.; J. C. Gilbert, Whitman, Mass.; Francis Greene, Providence, R. I.; Mrs. A. F. Hall, Boston, Mass.; Mrs. F. E. Hall, Quincy, Mass.; Mrs. F. H. Hayes, Boston,

Mass.; Mrs. James H. Higgins, Providence, R. I.; Mrs. Henry F. Jenks, Pawtucket, R. I.; Mrs. D. B. Kempton, New Bedford, Mass.; Miss Leonard, Middleboro, Mass.; Mr. and Mrs. L. D. May, Lowell, Mass.; Mr. and Mrs. Nathaniel Morton, Plymouth, Mass.; Mrs. Edward C. Nichols, Reading, Mass.; Mr. and Mrs. James Miller, Plymouth, Mass.; Mr. and Mrs. Charles Pike, Yonkers, N. Y.; C. C. Potter, Fall River, Mass.: Mr. and Mrs. N. Rand, Taunton, Mass.; Mrs. George J. Ries, Weymouth Centre, Mass.; Mrs. H. W. Rogers, Haverhill, Mass.; Mrs. N. F. Ryder, Middleboro, Mass.; Mr. and Mrs. E. F. Sherman, Plymouth, Mass.; Miss Smith, Cohassett, Mass.; J. C. Sullivan, Middleboro, Mass.; Miss Sylvester, Middleboro, Mass.; Mrs. D. N. Tower, Cohassett, Mass.; Charles J. Underwood, *Engineering Record*, New York city; Mrs. W. H. Vaughn, Wellesley Hills, Mass.; Miss Wentworth, Lawrence, Mass.; Mr. and Mrs. G. E. Williams, Weymouth Centre, Mass.

"IS THE GAME WORTH THE CANDLE?"

BY

JOHN THOMSON, M. Am. Soc. C. E., New York.

(Read June 14th, 1893.)

It seems desirable and even necessary to make a brief explanation regarding the published title of this paper. The courteous invitation, extended by President Chace, to prepare a paper for the summer meeting of the New England Water Works Association, found the writer at a loss for a subject, even although no reservations were made as to its selection, and floundering around, as it were, at last replied, in effect, that he hardly thought "the game worth the candle," meaning to convey, of course, that the illuminator in this case would be our Association, while the "game" would be the writer, should he come before you. But either the ability to comprehend a joke in Massachusetts is as obtuse as that fellow Scott who required to undergo the surgical operation of trepanning to take in the point, or else this is a case like Hamlet's, in which "the engineer is hoist by his own petard." But when, moreover, it was strongly intimated that a member of this Association would be liable to expulsion should he decline an invitation which, at the option of the guest, might have a *liquid* termination, it is doubtless needless to mention that the invitation was forthwith accepted. It is now proper to say that in attempting to fit this paper to your President's title, the limited time at disposal has rendered it necessary to draw upon a previous effort; so that the paper in fact will consist of a few brief opinions and observations in relation to features connected with the Commercial Side of the Water Meter Question.

The assertion is first ventured that there are fifty water works men today where there were but five ten years ago, who not only strongly believe in and advocate the use of water meters in general, but who also believe that every new service connection ought as uniformly to be provided with a meter as with a stop-cock. Undoubtedly, however, the element of cost is a considerable limitation to such a general introduction and use of meters. And this at once leads to a second assertion that the principal limitation to the reduction of prices for water meters is largely due to the two following conditions, namely: the degree of sensibility required at low rates of flow and the capacity to also safely operate under conditions involving high rates of delivery.

For years the writer has been searching for small things—the fine edge in first principles; the obscure detail which in the fabrication of mechanical devices is so often the key which opens the door to success, or gives a logical reason for a failure. But what should be the measure of the value in such cases, the mere finding of the thing itself, or that which it produces? And what should be the limit; for in mechanical refinement, as in the vastness of

space, "end is there none." From the high plane of scientific investigation, pure and simple, there is, of course, only one reply; but from the medium line of commercial considerations the answer may not be so certainly given. If we have many times to change the value of cubic feet into United States gallons for the purpose of comparison, does it repay the consumption of phosphorus and of time to multiply by 7.48 instead of 7.5 when it is the comparison of numbers and not the accuracy of the result in gallons that is sought? Does it pay, if desiring to know the circumference of a hemlock log, we multiply by three and four decimals, then peel off the bark and make no allowance for *tare*? Please do not by this conclude that the writer would belittle the value of the decimal point; its importance can hardly be over estimated. But it is to the disposal thereof that we are now contending, for it is a nice thing to know on *which side* of the full number to wisely place it, whereby to obtain the most economical results, when judged from the standpoint of every-day common sense requirements.

And with these reflections in mind it will readily be apprehended that the topic selected may be variously applied. For the time being, then, the writer would be regarded as a Public Economist in Water Works Equipment and the first application of our caption to be this:

For ordinary domestic service, is a high degree of sensibility in water meters at low rates of discharge worth what it costs? In other words, is the revenue derived from the measurement of "driblets" a sufficient compensation for the additional cost of the investment? 'Is the game worth the candle?" As the writer has before adverted to this subject in a paper entitled "A Memoir on Water Meters," presented to the American Society of Civil Engineers, and which his eminent friend, Mr. Emil Kuichling, M. Am. Soc. C. E., Chief Engineer of the Rochester (N. Y.) Water Works, discussed with partial reference to placing the decimal point on the left hand side of the numeral, a few excerpts from the paper and its discussion, taken from the Transactions of the American Society of Civil Engineers, Vol. XXV, June, 1891, may not be here out of place, the more particularly so as it was these portions of the paper which received the most extended notice at the time of its presentation.

In regard to accuracy in the registration of meters, the following excerpt is quoted:

"In Europe the necessity for economy in the public meter service is probably accountable for the much greater use of meters which there exists than in America. It is certain, too, that the employment of meters abroad has resulted in a satisfactory reduction of the water-waste, notwithstanding the fact that this has been largely accomplished by the use of the low-priced and comparatively inaccurate types of inferential meters. Hence, there is here presented the apparent necessity for close measurement, but with satisfactory economical results being derived from the employment of what is generally conceded to be the most inaccurate type of domestic water-measuring instruments.

"With us, however, it is but a slight stretch of poetical license to say that, when the water works engineer, who for years has stood complacently by

while water has been wastefully served at from 75 to 150 gallons per capita per day, who then suddenly concludes to apply a few meters to check this lavishness, his economy goes not only to the dollars but to the pennies; the meter is required to measure down to drops, and a standard of accuracy is not infrequently set up which but few laboratories have the means of verifying, and fewer water works employes the ability to carry out.

"The point of this is that for all practical purposes, in ordinary public service, a meter which would register to within 5 to 7 per cent. of accuracy, between fair minimum and maximum rates of discharge, is, in the writer's judgment, as in that of many others, amply accurate to effect the desired purpose. And when our water works officials will have arrived at the same conclusion, meters may then be purchased at a discount from present prices of from 20 to 25 per cent. Furthermore, such a standard of accuracy would, in ordinary practice, result in decreased cost of maintenance and increased life to the meter, because of the practical conditions of service under which meters are frequently set."

A portion of Mr. Kuichling's admirably prepared rejoinder is quoted as follows:

"While it may be conceded that the only rational way of charging and paying for water consumed by individuals or corporations is by meter measurement, yet the present cost of these measuring devices and their maintenance is generally regarded as being altogether too large to render their extensive introduction expedient in our large cities. Many water works officials would doubtless cheerfully recommend, and perhaps strongly urge, the adoption of meters for all classes of consumers, if they could obtain reasonably accurate, sensitive and durable machines at somewhat lower prices than appear to prevail at the present time; and it is mainly in consequence of existing prices, which the public regards as too high, that all efforts to introduce a general meter system have, in the majority of cities, met with determined opposition.

* * * * * * *

"It is very justly said that water is not sold to consumers by the drop or driblet, but by the gallon or the cubic foot, as the smallest practical unit. To this statement no one should take exception, but it is also fair to take it literally. Let the meter be sensitive enough to record, even with wide margin of accuracy, the fact that hundreds of gallons pass through it in the course of a day, and it will be a far more useful instrument to the community purchasing it than one which will exhibit marvellous accuracy in the measurement of comparatively large streams, and yet allow small flows to escape without detection. The percentage of error in registration of a meter is therefore a matter which should be sharply defined, and should be made dependent upon its sensitiveness. * * * * * * *

In the case of meters intended for family use, which in a general meter system would vastly outnumber all other kinds, it is, therefore, essential to make sensitiveness a paramount feature, as well as durability and cheapness. The same requirements may also be made for meters for the majority of manufactories and places of business in a community; and in the comparatively

few instances where the draught is constantly large, special meters which give a high degree of accuracy can easily be applied.

"In conclusion, therefore, it may be stated that a thoroughly serviceable meter would have a large sensitiveness, but need not have a very high degree of accuracy. How these qualities can be combined with durability and economy is a question whose solution is left to the skill of inventors."

To Mr. Kuichling's discussion, still referring in particular to the matter of accuracy, the following reply was made:

"As to lowering the standard of accuracy, this is a suggestion which I made with considerable hesitancy, as it might be taken as appearing to advocate a step backward. Nevertheless, I am of the opinion that, in at least the great majority of instances in which meters would be comparatively largely employed, the fact of whether or no they indicated at comparatively low rates of flow would bear but a very small relation to the total advantage and revenue derived therefrom. The point made by Mr. Kuichling to permit a lowering of the standard of accuracy, while yet retaining the element of sensitiveness to such a degree as to at least indicate a portion of the entire quantity at the lowest practicable rates of discharge, is somewhat in line with the results obtained in the use of the low-priced inferential meters, a type but little known in this country. This is a condition of operation, however, which would probably be very difficult to obtain, if at all, in the existing types of positive displacement meters."

In the first of the foregoing quotations the point was not made as clearly as it should have been, that an accuracy limit of from 5 to 7 per cent. was intended to refer in particular to operations at low rates of flow, because it is a fact that nearly, if not all, of the existing types of positive displacement meters may be calibrated to indicate with practical accuracy through a wide range in rate of delivery, although not capable of registering at a predetermined low rate of flow. The reason for this is that until the static resistance of the device is overcome, the freely fitted parts permit leakage, but immediately the mechanism is put into operation the error, if represented graphically, as by a line, would rapidly rise until at and beyond a given rate of flow the leakage, or "slip," as it is termed, becomes practically constant and will remain so, provided excessive wear of the parts does not take place. Now, in the instance, say, of a tightly fitted piston, or any equivalently positively operated device, which requires a considerable difference of pressure to operate it, the tendency is at once increased to cause leakage, or increase of "slip," and by this very fact to increase the likelihood of carrying particles of fine dirt or sand between the bearing surfaces. Again, the immediate consequences of such introduction of foreign particles is, by action analagous to that of a wedge, to still further increase the resistance of the device and wear of the parts. Thus in a machine, the first and the desirable effect of wear upon the journals is to bring the surfaces into more intimate contact by working down the high parts which first impinge against each other; but in a meter, referring to the instance being illustrated, the opposite effect is incited, that is to

decrease the intimacy of contact and provide a free film of water between the parts.

There are thousands of meters in actual service today performing well, returning a satisfactory account of their stewardship and earning a proper revenue, which if now tested at many of the low rate requirements would not pass muster and yet there has been accomplished upon the meter by wear of its parts what had probably been best definitely performed mechanically, that is, its bearings have been ground to a clearance.

What has just been said refers, as it will of course have been understood, to meters set under ordinary direct service, which is the only proper condition to which modern compact "rotaries" and also many of the "piston" types of meters, are adapted.

Now, the writer is not prepared to take a strong position upon this matter, rather hoping to derive information from the discussion of others more competent, nevertheless, he is strongly inclined to the opinion that, for the regular direct domestic service, a comparatively slight lowering of the usual standards of sensibility in the presently popular "rotary" meters would be of mutual advantage both to the purchasers of such meters, and to the manufacturers thereof. And attention is called to its being a "mutual" advantage, as the writer does not pretend to come before you with a scheme involving either charity on the one hand, or the missionary element on the other. The advantage to the purchaser would be in increased durability and decreased cost, the two, being of greater value, probably, than the quantities lost by lessened sensibility. The advantage to the manufacturer would probably be in the increased demand for his product, which, when taken together with the decreased cost of manufacture and calibration, would more than compensate the reduction in price. Consequently, the benefit would be *mutual*.

The extreme positions taken on this subject by engineers of recognized ability, is a lesson in the power of human judgment to distend without passing the "elastic limit." Thus, in a further discussion of the paper referred to, Mr. D. McN. Stauffer, M. Am. Soc. C. E., formerly city engineer of Philadelphia, said editorially in his paper, "Engineering News," as follows:

"In a memoir upon water meters, read last week before the American Society of Civil Engineers, at Lookout Mountain, Mr. John Thomson justly remarked that there is a demand on the part of corporations for altogether too much accuracy in water-measuring machines. He says that an error of five to seven per cent. would really be unimportant when the essential purpose of a water service is considered; and that the resulting gain from this allowance of error would be a much less costly and yet a more durable meter. We fully agree with Mr. Thomson. Water is sold by the gallon and not by the drop, and the only reason for measuring it out through a meter is to closely approximate to the actual quantity furnished, and to thus check the wholesale waste prevalent under the older methods of service. A few hundred gallons more or less, in a year, in the amount furnished to a consumer, is of little real importance; but it is important to stop the same man from absolutely wasting thousands of gallons in the same period. Water is a commodity that

should be made as nearly free as possible for all legitimate use; and a serviceable meter is the best regulator of this legitimate use. Its utility is fully recognized by all purveyors of water, and the comparatively expensive character of the machine and the cost of keeping it fully up to established standards of accuracy are the only limits to its common adoption. If the small error mentioned by Mr. Thomson will enable the price to be reduced from 25 to 30 per cent. below present market prices, and at the same time furnish a meter that will cost less in repair, there seems to be no good reason for rejecting his advice. A change of this kind would at once vastly extend the use of meters, and no one can question the gain in waste prevention, as compared with the older and very reckless methods of furnishing water. With only six meters, as yet, to every 100 taps in the United States, our readers can judge for themselves of the field still to be covered by this useful regulator of domestic and general water supply."

Then my good friend, and thoroughly practical engineer always, Mr. Robert Cartwright, M. Am. Soc. C. E., basing his judgment upon an experience with some tens of thousands of *gas* meters, says that he is prepared to reduce the water waste to a satisfactory rate by the simple use of meter *casings*, having no internal mechanism whatever; upon the theory that the *moral effect* upon individuals who suppose that the water which they are using is being measured, would have the desired result. On the other hand, Mr. Kuichling has pointed out, with an incisiveness which may well make the "meter man" wince, that the maintenance of meters "is generally regarded as being altogether too large to render their extensive introduction expedient in our large cities." And yet the requirements which he would insist upon are precisely those which both increase the cost of the meter and render it more likely to become damaged in practice. The query may well be here injected, if the saving in first cost and in cost of maintenance were invested in additional meters, would not the sum total of receipts and results be upon the side of the municipality?

It will be observed that the writer has made no suggestion as to what the proper minimum rate of test ought to be, believing that this can best be answered by the membership. It involves several interesting points, and so far as he knows has never been considered with the view of establishing uniformity of practice.

The second application refers to an opportunity open to the purchasers of water meters, and one which is almost entirely to their advantage, having in mind the existing state of the art. This refers to the selection of the proper size, or capacity, for the minimum service intended. In the aforementioned paper this was briefly referred to as follows:

"One of the most difficult experiences met with in practice has been to make clear to many water works superintendents that, in selecting the size of of a meter, conditions of operation have frequently much more to do with the quantity discharged than the mere matter of pressure." * *

* * "From whence it follows that probably three-fourths of the meters in public use today are considerably underworked; and that, if

proper judgment could be depended upon in selecting the capacity of the meter to the duty to be performed, still more compact and less expensive nominal sizes might be the result"

The opinion then expressed has been but strengthened by experience meantime gained; and while there is no more exasperating and inexcusable fault than to set a meter so as to be damaged by over-running, a fault promptly made evident, but little is ever said or known regarding the opposite condition, that is, under-running, which prevails to a much larger extent than is generally supposed. The reason for the latter is probably too often due to the greater convenience of measuring the diameter of the pipe, to which the contemplated attachment is to be made, rather than measuring the quantity which the pipe can deliver.

The writer believes that there is but one reliable and satisfactory method for practically determining the proper maximum capacity of a meter to be applied to a service, namely: to insert a meter in circuit, open all the valves or faucets and *time the operation of the meter* for one, five or ten minutes. Thus, if a $\frac{3}{4}$-inch meter has been set and its full delivery is only, say, $1\frac{1}{2}$ cubic feet a minute, then in the majority of cases a $\frac{5}{8}$-inch meter would satisfactorily replace it and so on through the range of sizes.

The proposition has also been previously set up by the writer that in his "belief and judgment, the proximate increase of efficiency in water meter practice will come quite as much from the better knowledge and practice of water works employes as from direct improvements in meters by manufacturers and engineers." And the points just made in regard to the selection of a proper capacity of meter, the one best suited, not to the diameter of the pipe, mayhap, but to the volume which it will be required to deliver, is directly in touch therewith. A new engine is not selected for an old factory by the diameter of the existing main-shaft, but upon an approximately definite knowledge of the machinery to be driven, and the power necessary therefor. But this illustration ends here, for in the instance of the engine, the required power may be predicted within the range of practical requirements, while in the case of the meter, a formula is yet to be written which will disclose the interior condition of valves, "department" stop-cocks, and such service pipes as have received the usual supply of plumbers' "trade marks." Hence, the expressed opinion that there is but one reliable plan to follow, at once convenient and eminently practical, namely: to apply the meter, time its delivery, and thereby ascertain its rate of operation, The commercial advantage of closely looking after this feature of meter practice will be almost entirely on the side of the purchasers of meters. In many cases where a meter smaller than the pipe is selected, it will have a two-fold advantage, effecting both a reduction in the first cost and by deriving the increased sensibility of a smaller instrument.

Regarding the maximum capacities of meters as published by the different meter companies, they in fact mean but little, and are often deceiving and disappointing. It is like saying, Given the requisite head, and the supply, and the conditions, and we will blow as much water through a nozzle of 2 inches

diameter as the other fellow with a nozzle of 2½ inches diameter, the mental reservation being made, however, that "we" will design and fabricate both of the said nozzles! The table of greatest proper quantities per minute, promulgated, it is understood, by the late Henry R. Worthington, is probably the nearest to a proper scientific basis—that is, velocity of flow through the pipe—of any known to the writer, as the controlling merit of those tables which have been developed more recently, would seem to be in the higher figures employed. Such tables may be taken as representing the very highest rate of operation at which the meter should be operated under extreme conditions—as in increased pressure for fire service—while for any fairly uniform rate of delivery all published maximum rates should be considered as in the case of list prices, *subject to discount.*

The third general application has reference to the matter of obstruction to the flow; which is often an important one in meter practice, and in this connection it may be well to call attention that the mere exhibition of a meter-device operating under a slight head, or by blowing or exhausting, should be understood as simply demonstrating the mechanical resistance of the parts, and is quite independent of the loss of head which may be due to tortuous water passages, or restricted ports. The complete and ready demonstration in such cases, where it is necessary or desirable to know the extent of the obstruction, is to note the time required to discharge a certain quantity into a trial-tank both with and without the meter in circuit, being careful to observe that *all* the conditions of each test are identical.

In conclusion, a few general observations, not to say, predictions, may be admissable. As in surgery, mechanics, engineering and the arts, sub-division of the art and sub-division of the section has resulted as well from necessity as from adaptation and desire. The day has surely passed when an admiring community shall pause awe-struck before an individual, because possessed of the universal knowledge of his time, and of whom it was recorded:

> "And still their wonder grew,
> To think that one small head,
> Held all he knew."

The day of division in the selection and use of water meters is at hand, if the water works purveyor would obtain the most economical returns, for there is no meter now on the market, nor is there much likelihood of its being devised, which will at one and the same time give equally satisfactory results under all conditions, when measured by the gauge of economics. From whence it follows that special services require as fair an exercise of judgment in the selection of the meter for the duty to be performed, as in the instance of a pump designed to feed a boiler, or to drain a mine.

In a table prepared by the writer in 1891, for the already too frequently mentioned paper, it was shown that the relation of meters to taps in the United States was only slightly over 6 per cent. This was subsequently taken up by one of the technical papers and, according to present recollection, the relation which it found was about 7 per cent. These figures were

obtained from the most reliable source then at hand, and were probably the first compilations of the kind ever made. They will be of particular value, however, should the opportunity again be taken to make a comparison at a yet later date; as it is the belief of the writer that, although from 35,000 to 40,000 water meters are now being made and sold every year in the United States, the water services are nevertheless probably being increased at nearly, if not quite, as rapid a rate as is the application of meters. Consequently, unless the production of meters shall be increased at even a much greater rate than heretofore, it would then be fair to assume that the ratio of meters to taps will not materially change.

But the writer trusts and holds that this relation will not remain constant; he would not be a consistent member of the Colony of Meter "Cranks" if he thought otherwise. He believes that the increasing use of water meters is a Public Benefit; that the suggestions herein contained, were they but partially carried out, would result even more beneficially; moreover that such benefits would be mutual; and hence, the "game" may be "worth the candle" to us all.

DISCUSSION.

MR. WALKER. I would like to ask how it would be where a tank is used? You say the meter might be made cheaper and more durable if it was not designed to register very closely. Where water is fed into a tank and afterwards drawn from faucets, the water can run slowly into the tank. Wouldn't a person get more than his money's worth of water in that case?

MR. THOMPSON. I think you are right. I particularly specified in the paper that I referred to the direct connection of meters in regular service, and I had in mind just such a condition as you mention. In a case of that kind it requires as close a degree of sensibility as is possible. It is one of the most difficult conditions found in practice—tank service such as you refer to; and I did not have that in my mind when I suggested lowering the senisbility as set forth in the paper.

THE PRESIDENT. Mr. Brackett has had a good deal of experience in testing meters, and we would like to hear from him.

MR. BRACKETT. I would say that I agree to a large extent with Mr. Thomson's conclusions. I think that while there might be some loss by the use of meters of a less accuracy, yet, as Mr. Thomson says, the proportion of loss would be very slight as compared with the total amount which is measured. The great objection to the adoption of such meters would be the tank service; and as the tendency in a great many cities now is to oblige the use of tanks in all cases, the difficulty there would be a practical one. However, even with a tank service I think the meter would register a very large percentage of the total amount used. The statement made by Mr. Thomson in regard to the small proportion of services which are now metered, is, I think, somewhat misleading, because what we really wish to know is the quantity of water which is used, and while the percentage of taps that are metered is only six or seven the proportion of the consumption used through meters is much larger. In Boston about seven per cent. of the taps are

metered and something over 27 per cent. of the total consumption. In New Bedford only 2 per cent. of the total number of services are metered but they meter between 20 and 25 per cent. of the total consumption. The proportion is larger there than in Boston. The fact which I have noted is that in 1890, New Bedford, with 140 meters, metered more water than Fall River, with 3,700 meters. The probability is, especially in the case of large meters, that the loss through an inaccuracy of five per cent. would be very small.

MR. WALKER. We buy our own meters and furnish and set them for nothing, and we have got a mimimum rate of $12. I am satisfied it does not pay, if you have plenty of water, to look after those meters and furnish the water for $12 a year. If you have little water it might pay; but if you have plenty of water it don't pay to look after a meter and keep it in repair, as they are making them now, for $12 a year. I think we should have a fifteen or twenty dollar rate, as far as our city is concerned. We have a good deal of trouble with our meters, and it makes no difference what kind of a meter it is, I think we have all kinds, and we have trouble with them all. But they are all accurate enough to detect a leak.

AN EXPERIENCE WITH A STAND-PIPE.

BY

JOHN C. CHASE, Superintendent, Wilmington, N. C.

(Read June 15th, 1893,)

The system of water works which the writer has in charge, was constructed some twelve years ago, and was among the very first built on the franchise plan. Two local capitalists were interested in the scheme, by an outside party, whose chief end was, apparently, to secure the contract for constructing the works. A valuable concession and contract, for a term of thirty years, was secured from the city, and, in due time, the same was transferred to a company organized under legislative charter.

The works were built without any engineering advice, so far as the owners of the system were concerned, except that furnished by the interested contractor. A local surveyor was employed, and given the title of engineer, but it is hardly probable that he had ever seen a water works plant, and all he apparently did was to sign such certificates as were prepared for him, and draw his pay.

One feature of the system was a stand-pipe twenty feet in diameter, and seventy feet in height, which was nearing completion when the writer arrived to take charge of the works.

This structure was a plate-iron cylinder, made of sheets three feet in width, and having a 6"x6" angle-iron on the lower edge, with the horizontal leg turning outward. It was erected on a masonry foundation without any anchorage, and without any bottom, the latter being replaced with an internal layer of cement concrete about one foot thick.

The parties who furnished the material say that they "gave the contractor a price for the complete structure, which was afterwards reduced in consequence of leaving out the iron bottom, which was his own suggestion."

The cause of this change is well understood by the writer, but it does not call for explanation in this connection.

The concrete bottom did not prove to be water-tight, and was taken out.

The next move of the builder was to pick out a recess under the bottom of the angle-iron, and pour a lead joint entirely around the outer circumference,

expecting to be able, by calking, to make a tight joint between the metal and the masonry. As might have been expected, this was a lamentable failure, and recourse was had to a new layer of concrete.

Before this was in condition to use, the contractor deposited, with disinterested parties, a sum of money sufficient to provide an iron bottom in case the concrete was not satisfactory, or did not remain tight for a period of six months, and having, in the meantime disposed of his stock interest, retired from the scene, stating, however, that he was going to arrange for the immediate putting in of an iron bottom, in order to release the funds deposited.

Nothing further was heard from him, and the six months clause turned out to be merely a device to embarrass the Water company in the use of their property, but, in due time, they gained possession, and the first question was how to complete the work in a water-tight and workmanlike manner.

The treasurer of the company, who was also one of the largest stockholders, was a lumber manufacturer, and like the historic tanner, who believed that there was "nothing like leather," saw no reason why a wooden bottom would not be the correct thing, and proceeded to carry out his ideas, although the writer did not approve of the device.

This is one of the few cases where the "practical man" has scored an apparent victory over the engineer.

The bottom was made of two thicknesses of three-inch yellow pine plank, laid so as to break joints, all joints being filled with oakum, and then coated with pitch. The surface of the concrete was leveled up with a bed of cement mortar, on which the bottom layer of plank was bedded. Short braces, bearing against the bottom of the second course of sheets, were put in to keep the bottom from floating until it became thoroughly water-logged.

The leakage has been slight, and has not varied to any perceptible extent, except for a short interval after refilling the stand-pipe, when it has been emptied for any purpose.

As before stated, the writer did not approve of the method adopted, and claims no credit for its practical success.

It is perhaps unnecessary to say that notwithstanding the satisfactory result, he would not advise its future adoption, though a state of affairs requiring similar treatment can hardly be imagined to exist.

Inasmuch as the expense was less than one-fourth of the sum required for an iron bottom, the experiment was a *financial* success, and the members of this Association are probably well aware that such results appeal far more strongly to the heart of the average capitalist than any amount of abstract theorizing from an engineering point of view.

The prospective removal of the structure to a different location is anticipated with pleasure, as it will give an opportunity to complete it in accordance with long tried and approved methods.

Further comment is unnecessary, and each one can point the moral to his own taste.

In conclusion, it may be said that the stand-pipe was soon found to be of inadequate height, and an addition of twenty feet was made to the top.

The inside staging having been removed, and the outside one being considered unsafe, the extension was erected from a float containing a balance derrick, which enabled the sheets of a course to be raised and swung to the proper position in a very expeditious manner.

The rivets were driven on the inside, and held on the outside by a workman suspended in a cage, carried by roller hooks traversing the top edge of the course of sheets, on which work was being done.

The riveting of the course having been completed, the seams were calked, and water then pumped in until the float was raised to the desired height for another course.

This method of construction has the advantage of testing the work as fast as completed, and the writer believes this to be the first time the method was used. It has been in frequent use since, and is of great advantage where the pumping machinery and connections are completed before the stand-pipe is erected.

WATER PIPE TRENCHES VS. GOOD ROADS.

BY

W. E. McCLINTOCK, C. E., Boston, Mass.

(Read and illustrated by stereopticon, June 14, 1893.)

The wants of modern civilization are many, and the civil engineer has to be often called upon to satisfy some of these. If we cast a glance backward to the beginning of the present century, we shall see that about the only demand for skilled engineers was in laying out and constructing canals. The same men who gained experience in this line of work naturally took charge of the steam railroads, when their construction began, shortly after the close of the first quarter of the century. Near the middle of the century, the important question of obtaining a supply of water from outside sources was inaugurated by Boston; and not long after, it became imperative to remove the increased wastes, and sewerage began to assume importance. Today, every town of any considerable size has its water works, and they are fast putting in sewers. Then came gas, electricity, and various other new works; and quite recently the engineer has been called upon to take up with highway engineering. While our own country was passing through the canal-building period, the foreign engineer was at work improving the highways as well as water-ways. During that time the two eminent Scotch engineers, Telford and Macadam, started out on their grand work in Great Britain; while the School of Roads and Bridges was being organized for the same kind of work in France. It was during that time that road building became an art; and even before the advent of the steam railroad, Great Britain France and Switzerland had succeeded in constructing a network of magnificent highways, many of them on the ruins of the imperial roads of Rome, which had in many cases been disused for centuries. There can be no doubt but what the present agitation in our own country will not be dropped until our roads are the equal of any country in the world. We have the money, the materials, and the brains, and it looks now as if these are to be mixed in the proper proportions. The civil engineer is often a destroyer, as well as a builder up. Water works, sewerage works, gas works and street railways are certainly most destructive of good roads. In all of these works, the civil engineer has a hand at the very start, an inspection during construction, and a final approval; and it lies with him, to a large extent, to say what shall be and what shall not be done. It is surely a short-sighted policy which will not allow us to see beyond the work directly in hand, to a work of nearly, if not quite, equal importance. It is our duty to respect all kindred works, and do all within our power to maintain, if not improve, them. What is the general practice of most of us as superintendent of water works, when our duty calls

us to lay a water pipe, either main or service, and in so doing dig up a street? What do we do with the trench? I have taken a few pictures of such trenches as they were left, and they will look familiar to many of you, I am sure.

Here is one near a hydrant, where the wheel sinks in over eight inches, and large stones lay scattered about the ground. The road on both sides of this trench is good and smooth, and the first intimation I had of the hole was when my wheel went into it, and I nearly broke both neck and wheel.

Here is another hydrant trench, cut in a good, hard roadway, on a street lined with fine residences. The back fill was made without any attempt at ramming, or care in covering large stones, and over the trench it was humped up five to six inches with a coarse, loose gravel, some of the gravel stones being four to five inches in diameter. This gravel will not compact inside of four to six months and when it does, there will be a deep hollow in the middle, and a ridge on each side, where the gravel has been crowded out over the firm ground.

Here is a trench through a firm, smooth, macadam road; an old pipe was taken out, and a new one of the same size put in. All our text-books tell us that excavated earth shrinks when put into another place; but this shows a ridge along the road which is fully three inches high. The whole road is disfigured, and will remain so, perhaps, for years. Here is a picture of a main being extended across a road. The back fill is loose gravel and coarse stones, an eyesore to the abutter, a menace to the unwary traveler.

I say such things are wickedly wrong; all the more so, because they are so easily preventible.

We know there are two kinds of water trenches,—the new, clean trench, and the one caused by a broken main.

The new trench, when properly back-filled, should be a benefit to the roadway, as it often affords much needed drainage. I have often seen the part of a roadway over the water trench dry and hard, when the rest of the way was almost impassable. This resulted from putting all the stones at the top of the trench, just below the surface, where they served the purpose of a Telford foundation, and afforded excellent drainage.

I should say that the first step for you to take, as water works men, would be to pay strict attention to this part of the work. It would add but little to the cost of your work, and would place you in the ranks of road-builders, instead of destroyers. In excavating, first have the upper few inches of a roadway carefully laid to one side, the remainder of the excavated material on the other side of the trench. While this is ordinarily intended to be done, there are but few cases in practice where it is strictly attended to, and even though it be, no good will result, as the bottom of the trench may not be rammed, and it is an even chance if the original top layer will not be carried away. In case of a break, the light material is washed out, and the stones are at the bottom of the trench, or the whole mass of earth is saturated with water, and entirely unfitted for back-filling. This is particularly true during freezing weather.

The only remedy for such cases that I know of is to remove the water-soaked material, and put in its place dry gravel or other material, and carefully ram it. If the gravel used be loose and clean, it may be compacted easily by spreading over the top a covering of dirt, free from stones, and then ramming carefully, leaving the surface as near even with the original roadway as possible. If the roadway be macadam, broken stone, properly screened, should be placed on top and rammed thoroughly, and covered with from one to two inches of stone dust.

You may say, "this is no part of my business as superintendent of water works." But I say it is your business to leave things in as good condition as you find them; and until you do this, you have surely failed in your duty.

Some good authority states that earth moved from bank to fill, shrinks, the shrinkage varying with the material, it being greatest in puddled clay and least in gravel.

TABLE OF SHRINKAGES OF EARTH.

Gravel	8 per cent.
Gravel and sand	9 " "
Clay	10 " "
Loam	12 " "
Puddled clay	25 " "

In a small experiment, I excavated a trench in a clayey loam to a depth of one and one-half feet. The back-fill was rammed dry, in layers of not over three inches, and the excavated material filled the trench within two inches of its top, or about 11 per cent.

In case we were to lay a 12-inch pipe in a trench 4½ feet deep and 2½ feet wide, the shrinkage should be .59 of a foot deep, or 1.475 square feet in section, which is equivalent to a circle of about 1¼ feet. If this is correct, we should lay on 12-inch pipe, put all the excavated material back, and leave no ridge on the surface.

In putting in some pipes for storm-water sewers in Belmont, our specifications were that the trenches should be carefully and thoroughly rammed, all the excavated material being put back, and the surface of the roadway be left even and smooth, with no ridge. The pipes varied in size from 8" to 12", and the work was done as specified, although I had strong doubts of it at the start.

Different materials must be back-filled in a different manner. I have made a few crude experiments in this direction, which may have some value.

The three trials I will refer to were as follows: with clean gravel; gravel containing more or less clay and loam; and fine hard-pan or boulder-till.

First experiment: with clean gravel. The gravel was all placed loosely in a tub, and was 5.33 inches deep, after ramming dry. A second trial was made by ramming in layers of about two inches, which resulted in leaving the depth 5.3 inches. A third trial was made, which consisted in placing the gravel in layers of about two inches, wetting just enough to moisten, and ramming each layer; the result was just the same as by the last method.

Clean gravel or sand will unquestionably pack closer when dry than it will when it is wet.

Haswell gives the weight of a cubic yard of dry, loose sand as 2632 pounds, and of damp sand as 2349. That is, the dry sand will weigh about 12 per cent. more than the damp, provided it is put in loose, without ramming.

The experiment referred to above shows a settling of about one-half of one per cent. by ramming in thin layers, and this was not changed by applying water, either in large or small quantities.

If all the fragments which make up a gravel are in close contact, there can be no future settlement. But it is possible to have a good percentage of quite fine sand intermixed with the larger fragments. If the mixture is perfect, the smaller bits will fill the interspaces of the larger, and there will be no settlement. The difficulty is to secure a complete mixture of all the different sized bits, and at this point we find the ramming comes into play. By jarring the whole mass, the finer sand is sifted down so as to fill the voids. This process might be assisted by water; but I should say that it should be applied in large enough quantities to wash the finer bits down. There is no doubt, in my own mind, but a trench in sand or gravel can best be back-filled without water and with a moderate amount of ramming.

Second experiment: with gravel containing more or less clay and loam.

The material used for the experiment was taken from a trench which is now being worked on, and I will show you pictures of the way in which the work is being done.

The dry gravel was all placed in a tub, and was 6.23 inches deep. It was thoroughly rammed, and then measured 5.75 inches deep,—a shrinkage of 7 $\frac{7}{10}$ per cent.

The second lot, dry, was then rammed in two inch layers, and measured 5.4 inches,—a shrinkage of 13 $\frac{3}{10}$ per cent. from the loose material, or 6 per cent. of the single rammed. The gravel was then placed in two inch layers, each layer was wet to moisten the material, and then rammed. The depth was thus reduced to 5.2 inches, or 3 $\frac{7}{10}$ per cent. of the dry ramming in thin layers. A thorough puddling and ramming reduced the depth only about one-tenth of an inch more.

The deduction I should make from this is that gravel and clayey earth can best be settled by a thorough ramming in thin layers, while dry or slightly moist.

Any ordinary trench can and should be so rammed that all the excavated material back be returned and leave no ridge.

If you wish to make a particularly good job, as far as the roadway is concerned, let your men throw the finer stuff into the bottom, leaving the coarser stone to fill the top six or eight inches of the trench, covering this with one or two inches of fine gravel. In this way you can make a good strip of road, even if the rest of it is bad, and it might serve as a penance for past sins of commission.

Third and last experiment: with hard-pan or boulder-till.

As many of you know, a trench through hard-pan is one of the most difficult to put back so it will not settle. The lumps of sandy clay are hard, and when thrown into the trench they lie like so many stones; but unlike stones, they will dissolve in water, and forming, as they do, a very porous mass, the water finds its way amongst them, and they gradually slack up, settle together, and cause a great deal of trouble for many months, if not for longer periods. If we can break these lumps up to a powder, there will be no future trouble. But while they appear to be quite fine, there are yet many interspaces which allow of settlement.

I first filled the tub with dry hard-pan, and rammed it thoroughly, when it stood to a depth of 6.1 inches. It was again placed dry, in thin layers, and each layer rammed, when the depth was reduced to 5.6 inches, or an $8\frac{2}{10}$ per cent. reduction from the single ramming.

It was next placed in thin layers, slightly moistened, and each layer rammed, when the depth was reduced to 5.5, or $1\frac{8}{10}$ less than the dry, thin layers rammed.

The whole was then shaken up and made quite damp and rammed thoroughly. The depth then stood 4.93 inches, or 12 per cent. less than the dry, thin layer ramming, and $10\frac{2}{10}$ less than the moist thin layer ramming. It is evident, from this, that the lumps of hard-pan are best broken up by a good moistening and a thorough ramming. The lumps are sufficiently fine to resist the action of water for some time; but while damp, they are easily acted upon by the rammer, and reduced to a sufficient degree of fineness not to settle any more.

I should dry ram all trenches thoroughly, using water on clay or hard-pan, and no water on sand, gravel, or sandy loam.

One fact we want to bear in mind, and that is, that any amount of ramming will only affect a comparatively thin layer.

Some years ago, we had a water pipe laid in a main street, which we intended soon to repave. The back-fill was made with no ramming; a little water was run on top, under the impression that it was puddling. The trench was filled to the surface of the pavement, and crowned a little in the middle. The heavy traffic of the street was turned over this for several months, until the surface was apparently as hard as the pavement itself, the heaviest wheels making no impression on it. We then removed the top twelve inches of this trench, put in the ordinary seven inch gravel bed, and laid on granite blocks in the best possible manner. With the first rain, our pavement over the trench settled, and it continued settling for some months, with each rain and had then to be entirely relaid. In this case the surface was thoroughly rammed, but the effect was felt only for a depth of a few inches. When the surface was removed, and the blocks substituted, the water easily found its way through the joints into the trench, and this was gradually puddled.

The same is true with rolling a road. The heaviest steam roller cannot compact stone that is more than four or five inches in depth. Any great depth may apparently be settled, but breaking up will reveal the fact that all stones from three to five inches below the surface are as loose as when they were

placed there. We must roll a road in thin layers, to do any good. We must likewise ram a trench in thin layers, in order to insure it against settling.

In these days, when extraordinary measures are being taken to improve the roads of our country, we cannot afford to hang back and refuse to perform our share of the work. We have no right to look solely at our own particular part of the work, and leave the rest to some one else. The additional cost of good work in this direction is but a small percentage of the whole, and if we but add it to our original estimate, it will be but a small loss to us, while it will be an inestimable gain to the traveling public.

DISCUSSION.

MR. FULLER. I have been very much interested in this paper and I heartily agree with what Mr. McClintock says. I have found it very difficult in my experience to get contractors to put the trench back in the shape we all desire to have it done, and I think perhaps one reason is that the price which is paid for doing contract work has been brought down to such a low figure that they cannot afford to do it. I do not believe that when a man gets from 20 to 25 cents a foot for laying 6-inch pipe he can so put back the material that has been excavated as to make a perfectly smooth, hard, flush surface. At one of our meetings some time ago a suggestion was made that work might be bid on in two ways, that is, there might be a price for putting back the material in the ordinary way, rounding it up and doing a certain amount of ramming, and also a price for ramming it so it will be flush and even with the surface. Then the parties having the work done could take their choice, and if they desire to have the work done the better way they could have it so done by paying for it. But I think that where a town is putting in, in one season, ten or twelve miles of water pipe, and they have none too much money to spend, it is pretty difficult to get the work done as you would like to have it, and the roads have to be left a little rough, and the next year smoothed off and finished up. I do not think that with a gang of Italians and the contractor driving them and hurrying along the work as fast as he can, which, of course, he is liable to do in spite of all you say to him, you can get the material put back in 3-inch layers and carefully rammed, so that when the work is done you will not know where the water trench had been dug.

MR. NEVONS. I have never in my experience seen water pipes laid where you couldn't find the ditch. Our method of filling is to throw in about a foot loose, and then fill the ditch about half full of water, and then throw in the dirt and break it all up, and we don't have any trouble at all. Of course we ram the top. We very seldom have to cart much of anything away, and I have known instances where we have had to cart material to help fill up the trench. In laying about eight miles of 30-inch main, a large proportion of which was laid through the streets of Waltham, and we also went through the main avenue in the cemetery, we used water whenever we could get it, and left our trenches so that we have never had to go back and put a shovelful on them since. The authorities commended us, and I think my friend the water superintendent in Waltham will bear me out when I say that we left

their streets in better shape than we found them. I think one of the most important things connected with water works construction is to leave the streets in good shape, and if we don't do it in our city we have the superintendent or the Mayor or somebody after us pretty quick, and we think we might as well do it as to have anybody else. I always want to use water if I can get it.

MR. DECKER. I have laid probably several hundred miles of pipe, and I have learned one thing, and that is that the hand of man never can place earth back as Nature puts it. I have found in my experience that with certain classes of soil I can get all the earth back and have to get dirt from somewhere else to fill up my ditch, while in another class of soil I can't begin to get all the dirt in. Like my brother Nevons, of Cambridge, I believe in the use of water. I find I can settle a ditch better by using water than I can in any other way, and I get a ditch that will give better satisfaction. I know some three or four years ago out in Kansas where the soil is peculiar, I don't know whether there is any such anywhere else on earth, I laid a 12-inch pipe, filled my ditch, flushed it in, and I lacked about six inches from the surface. With a four feet and a half ditch there we had to get about six inches to cover. I had never heard of its settling, and I don't think it has settled any.

MR. D. W. FRENCH. I believe in the use of water, and use it whenever there is an opportunity. When it is impossible to obtain it I have had trouble on account of settling.

TOPICAL DISCUSSION.

[June 15, 1893.]

"Details of Pipe Castings and Coating."

Mr. Brackett. Mr. President and gentlemen: Having been requested to open this discussion I have prepared a short paper upon one branch of the topic, viz: "Uniformity in the design for special castings."

In the specifications for water pipes the thickness and weight are generally carefully prescribed, and variations of more than from 3 to 4 per cent. from the weights called for are not allowed.

Special castings, however, are generally furnished of such patterns as the contractor may have in stock whether they be large or small, thick or thin, and as they are furnished by the pound the tendency is to have them both large and thick.

Even in cases where the castings are made from drawings furnished by the engineer or superintendent, there is a great difference in the weight of the castings furnished by different foundries from the same drawing.

As special castings cost about double the price per pound of the straight pipe, they should be made of as compact forms as is consistent with their convenient use, also taking into consideration the question of their influence upon the flow of the water in the mains. The frictional head lost in a branch is, under most circumstances, but a very small fraction of the loss in the straight pipes but under some circumstances, such as the branches supplying hydrants, elevators and motors, the difference in the discharge of a branch constructed so as to give an easy flow and one of the opposite form would be appreciable.

This is well illustrated by the sections of two branches, both made from the same drawing but cast at different foundries. In one case there is a smooth, well rounded approach to the branch, while in the other the opening is contracted, rough and nearly square edged.

Another point which appears to me to be worthy of consideration is the advantage of having special castings of uniform pattern. Under the present system the branches of the same size are of varying dimensions and the curves of different radii and curvature.

The pipe founders are often required to furnish castings of special design, causing delay and expense on account of patterns which must be made, when the standard forms would be equally serviceable if it were known that they could be furnished by the different foundries.

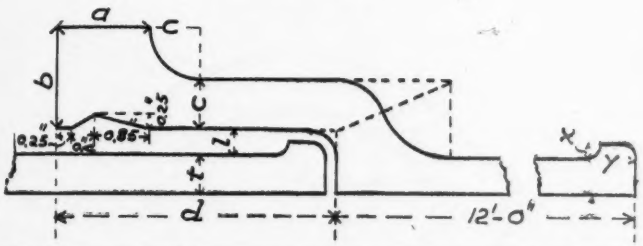
These preliminary remarks will explain my motive in presenting for your consideration and use the following designs for special castings. They are the standards adopted by the Boston water department and the principal foundries furnishing pipe to New England are already supplied with many of the patterns.

The dimensions of the bells and spigots, shown on Sheet No. 1 are applicable to all of the special castings.*

The general dimensions of the different patterns are given on the following sheets. The thickness of the castings, unless otherwise specified, agrees with the standard for pipe of the same internal diameter.

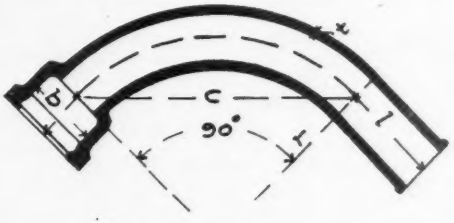
* See also Vol. III, p. 8.

PIPES.



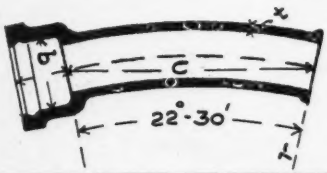
Diam. in Inches.	Class.	Dimensions in Inches.								Weight.
		a	b	c	d	t	l	x	y	
3	B	1.50	1.20	0.60	4.0	0.40	0.40	0.20	0.60	180
4	B	1.50	1.30	0.65	4.0	0.45	0.40	0.20	0.60	260
6	B	1.50	1.40	0.70	4.0	0.50	0.40	0.20	0.60	420
8	B	1.50	1.50	0.75	4.0	0.55	0.40	0.20	0.60	600
10	B	1.50	1.60	0.80	4.5	0.60	0.40	0.20	0.80	815
12	A	1.50	1.60	0.80	4.5	0.58	0.40	0.20	0.80	935
12	B	1.50	1.70	0.85	4.5	0.65	0.40	0.20	0.80	1050
16	A	1.75	1.70	0.85	5.0	0.66	0.50	0.25	0.85	1415
16	B	1.75	1.90	0.95	5.0	0.75	0.50	0.25	0.85	1615
20	A	1.75	1.90	0.95	5.0	0.73	0.50	0.25	0.85	1950
20	B	1.75	1.90	0.95	5.0	0.85	0.50	0.25	0.85	2250
24	A	2.00	2.10	1.05	5.0	0.81	0.50	0.25	0.85	2590
24	B	2.00	2.10	1.05	5.0	0.94	0.50	0.25	0.85	2985
30	A	2.00	2.30	1.15	5.0	0.93	0.50	0.25	0.85	3690
30	B	2.00	2.30	1.15	5.0	1.10	0.50	0.25	0.85	4335
36	A	2.00	2.50	1.25	5.0	1.04	0.50	0.25	0.85	4930
36	B	2.00	2.50	1.25	5.0	1.25	0.50	0.25	0.85	5880
40	A	2.00	2.70	1.35	5.0	1.12	0.50	0.25	0.85	5900
40	B	2.00	2.70	1.35	5.0	1.35	0.50	0.25	0.85	7050
48		2.00	2.70	1.35	4.0	1.00	0.50	0.25	0.85	6275
48	A	2.00	3.00	1.50	5.5	1.25	0.50	0.25	0.85	7920
60		2.25	3.40	1.70	6.0	1.375	0.50	0.25	0.85	10960

ONE QUARTER CURVES.

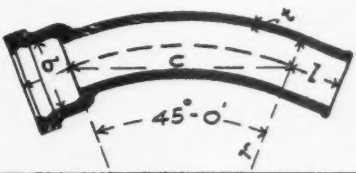


Diam. in Inches.	Class.	Dimensions in Inches.					Weight.	
		b	t	r	c	l		
3	B	4.6	0.40	16	22.6	8	55	
4	B	5.8	0.45	16	22.6	8	80	
6	B	7.8	0.50	16	22.6	8	125	
6	B	7.8	0.50	24	34.0	6	150	
8	B	9.9	0.55	16	22.6	10	185	
8	B	9.9	0.55	24	34.0	6	215	
10	B	12.0	0.60	16	22.6	12	260	
10	B	12.0	0.60	24	34.0	6	295	
12	B	14.1	0.65	16	22.6	12	330	
12	B	14.1	0.65	24	34.0	6	375	
16	B	18.5	0.75	24	34.0	12	645	
20	B	22.7	0.85	24	34.0	12	880	
24	B	25.9	0.94	30	42.4	12	1355	

1/16 CURVES.

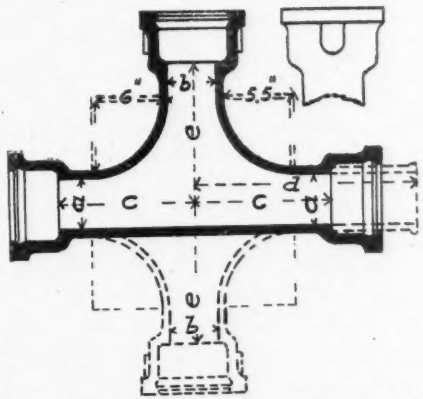


1/8 CURVES.



Diameter of Pipe.	Class.	Dimensions in Inches.								Weight.
		b	t	1/16 Curves.			1/8 Curves.			
				r	c	Weight.	r	c	l	
3	B	4.6	0.40	48	18.7	40	24	18.4	4	45
4	B	5.8	0.45	48	18.7	55	24	18.4	4	65
6	B	7.8	0.50	48	18.7	85	24	18.4	4	95
8	B	9.9	0.55	48	18.7	120	24	18.4	4	135
10	B	12.0	0.60	48	18.7	165	24	18.4	4	185
10	B	12.0	0.60	120	46.8	310	60	45.9	—	310
12	B	14.1	0.65	48	18.7	210	24	18.4	4	235
12	B	14.1	0.65	120	46.8	400	60	45.9	—	400
16	B	18.5	0.75	120	46.8	620	60	45.9	—	620
20	B	22.7	0.85	120	46.8	845	60	45.9	—	845
24	B	26.9	0.94	120	46.8	1125	60	45.9	—	1125
30	A	33.2	0.93	120	46.8	1405	60	45.9	—	1405
30	B	33.2	1.10	120	46.8	1620	60	45.9	—	1620
36	A	39.1	1.04	180	70.2	2615	90	68.9	—	2615
40	A	43.25	1.12	180	70.2	3130	90	68.9	—	3130
48	A	51.5	1.25	180	70.2	4215	90	68.9	—	4215

BRANCHES.



Dimensions in Inches.					Weight.			
					Three Way Branch		Four Way Branches	
a	b	c	d	e	Two Bells.	Three Bells	Three Bells	Four Bells
4	3	10.5	22.5	11				
4	4	11.0	23.0	11	125	125		
6	3	10.5	22.5	12	160	160		
6	4	11.0	23.0	12	165	165		
6	6	12.0	24.0	12	205	205		
8	3	10.5	22.5	13	200	200		
8	4	11.0	23.0	13	220	220		
8	6	12.0	24.0	13	250	250		
8	8	13.0	25.0	13	290	290		
10	4	11.0	23.0	14	290	290		
10	6	12.0	24.0	14	325	325		
10	8	13.0	25.0	14	360	360		

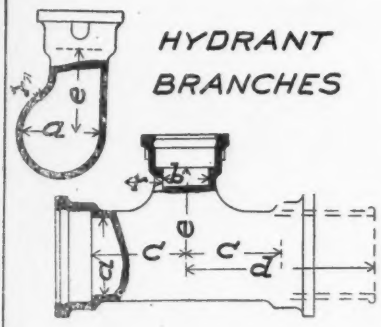
BRANCHES.

Dimensions in Inches.					Weight.			
					Three Way Branches		Four Way Branches.	
a	b	c	d	e	Two Bells.	Three Bells	Three Bells	Four Bells
10	10	14	26	14	400	400		
12	4	11	23	15	360	360		
12	6	12	24	15	390	390		
12	8	13	25	15	430	430		
12	10	14	26	15	480	480		
12	12	15	27	15	520	520		
16	4	11	23	17	550	550		
16	6	12	24	17	575	580		
16	8	13	25	17	625	630		
16	10	14	26	17				
16	12	15	27	17				
16	16	17	29	17				
20	6	12	24	19				
20	8	13	25	19				
20	10	14	26	19				
20	12	15	27	19				
20	16	17	29	19				
20	20	19	31	19				
24	6	12	24	21				
24	8	13	25	21				
24	10	14	26	21				
24	12	15	27	21				
24	16	17	29	21				
24	20	19	31	21				
24	24	21	33	21				
30	12	15	27	24				
30	16	17	29	24				
30	20	19	34	24				
30	24	21	36	24				
30	30	24	41	24				
36	12	15	27	27				

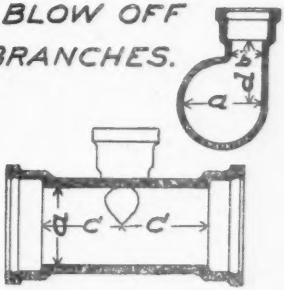
BRANCHES.

Dimensions in Inches.					Weight.			
					Three Way Branches		Four Way Branches.	
a	b	c	d	e	Two Bells.	Three Bells	Three Bells.	Four Bells
36	16	17	29	27				
36	20	19	34	27				
36	24	21	36	27				
36	30	24	41	27				
36	36	27	44	27				
40	12	15	27	29				
40	16	17	29	29				
40	20	19	34	29				
40	24	21	36	29				
40	30	24	41	29				
40	36	27	44	29				
40	40	29	46	29				
48	16	17	29	33				
48	20	19	34	33				
48	24	21	36	33				
48	30	24	41	33				
48	36	27	44	33				
48	40	29	46	33				
48	48	33	50	33				

HYDRANT BRANCHES



BLOW OFF BRANCHES.



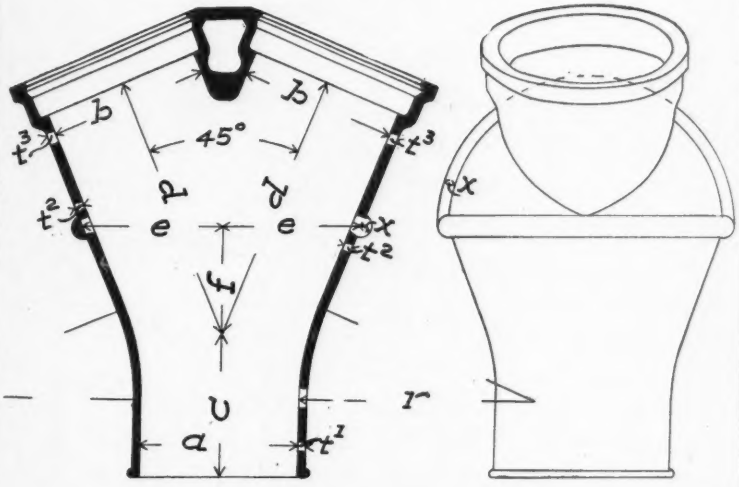
HYDRANT BRANCHES.

DIMENSIONS IN INCHES.						WEIGHT.
a	b	c	d	e	r	
10	6	12	24	11	5	
12	6	12	24	12	5	
16	6	12	24	15	5	

BLOW OFF BRANCHES.

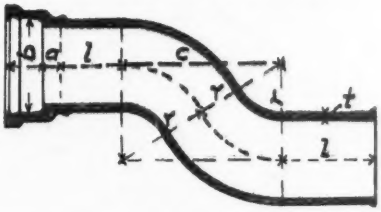
DIMENSIONS IN IN'S.				WEIGHT.
a	b	c	d	
8	4	10	7	
10	4	10	8	
12	4	10	10	
16	4	10	12	
20	6	12	14	
24	6	12	16	
30	12	13	20.5	
36	12	13	23.5	
40	12	13	25.5	
48	16	24	29.5	

Y BRANCHES.



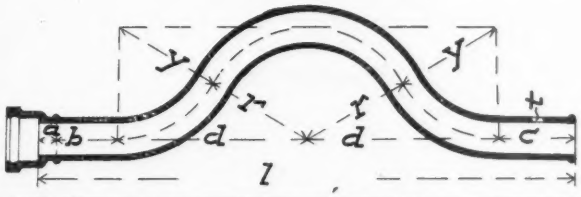
DIMENSIONS IN INCHES.											WEIGHT.
a	b	c	d	e	f	r	t^1	t^2	t^3	X	
20	20	18	34	17.6	13.5	30	0.85	1.10	0.85	1.25	
24	24	18	38	20.6	15.25	30	0.94	1.20	0.94	1.25	
30	24	12	38	20.6	15.25	30	1.10	1.20	0.94	1.25	
30	30	18	48	25.3	18.0	30	1.10	1.40	1.10	1.25	
36	36	18	54	29.8	21.0	24	1.04	1.50	1.04	1.50	
40	40	18	60	33.3	24.0	24	1.12	1.50	1.12	1.50	
48	48	18	68.5	39.5	28.0	24	1.25	1.75	1.25	1.50	

OFFSETS.



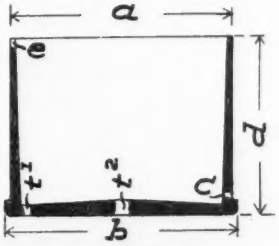
Diam. of Pipe.	Dimensions in Inches.						Weight.	
	a	b	c	l	r	t		
4	2	5.8	13.86	10	8	0.45	90	
6	2	7.8	13.86	10	8	0.50	140	
6	2	7.8	24.25	10	14	0.50	170	
8	2	9.9	17.32	10	10	0.55	215	
8	2	9.9	25.98	10	15	0.55	255	
10	2	12.0	20.78	10	12	0.60	310	
10	2	12.0	—	10	—	0.60	—	
12	2	14.1	24.25	10	14	0.65	430	
12	2	14.1	—	10	—	0.65	—	

SIPHON PIPES.



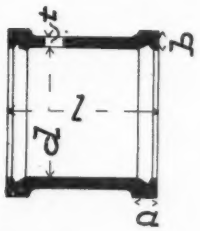
DIAM. OF PIPE.	DIMENSIONS IN INCHES. a	b	c	d	r	y	t	l	WEIGHT.	
4	2	8	8	24.25	14	14	0.45	66.5	150	
6	2	8	8	27.70	16	16	0.50	73.4	260	
8	2	8	8	30.00	18	16	0.55	78.0	400	
10	2	8	8	31.10	19	16	0.60	80.2	560	
12	2	8	8	32.25	20	16	0.65	82.5	740	

PLUGS.



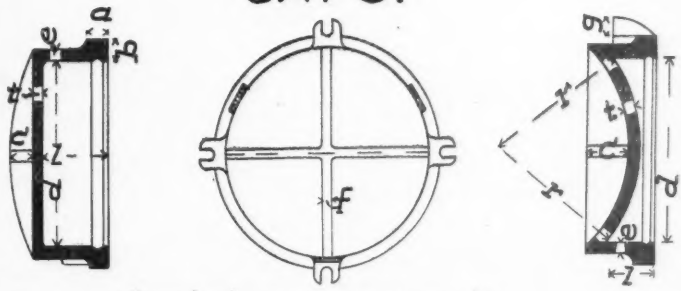
DIAM. OF PIPE.	DIMENSIONS IN INCHES. a	b	c	d	e	t^1	t^2		WEIGHT.	
3	3.8	4.20	0.25	5.5	0.125	0.35	0.35		4	
4	4.9	5.30	0.25	5.5	0.125	0.35	0.35		6	
6	7.0	7.40	0.25	5.5	0.125	0.35	0.50		10	
8	8.10	8.50	0.25	5.5	0.125	0.40	0.50		13	
10	11.20	11.60	0.30	6.0	0.20	0.50	0.60		28	
12	13.20	13.60	0.30	6.0	0.20	0.50	0.75		38	
16										

SLEEVES.



DIAM. OF PIPE.	DIMENSIONS IN INCHES.					
	a	b	d	l	t	WEIGHT.
3	1.5	1.2	4.6	10	0.6	35
4	1.5	1.3	5.8	10	0.65	45
6	1.5	1.4	8.0	10	0.7	67
8	1.5	1.5	10.1	12	0.75	100
10	1.5	1.6	12.25	12	0.8	130
12	1.5	1.7	14.35	14	0.85	185
16	1.75	1.8	18.75	15	0.9	275
20	1.75	1.9	23.0	15	0.95	350
24	2.0	2.1	27.2	15	1.05	470
30	2.0	2.3	33.6	15	1.15	640
36	2.0	2.5	39.6	15	1.25	820
40	2.0	2.7	43.7	15	1.35	980
40	2.0	2.7	43.7	20	1.35	1230
48	2.0	3.0	52.0	15	1.50	1290
48	2.0	3.0	52.0	20	1.50	1620

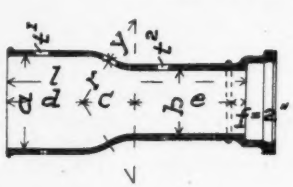
CAPS.



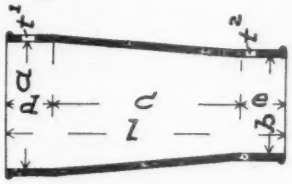
10" and 12" caps have two ribs.
16". 20" 24". 30" and 36" caps have three ribs.
40" and 48" caps have four ribs.

DIAM. OF PIPE.	DIMENSIONS IN INCHES.										WEIGHT.
	a	b	c	d	e	f	g	l	t	r	
3	1.5	1.20	—	4.6	0.60	—	—	3.75	0.50	—	18
4	1.5	1.30	—	5.8	0.65	—	—	3.75	0.60	—	25
6	1.5	1.40	—	8.0	0.70	—	—	3.75	0.65	—	40
8	1.5	1.50	—	10.1	0.75	—	—	5.	0.75	—	70
10	1.5	1.60	1.50	12.25	0.80	0.75	—	5.	0.75	—	95
12	1.5	1.70	1.75	14.35	0.85	0.75	—	5.	0.75	—	125
16	1.75	1.90	2.00	18.75	0.95	0.75	—	5.	1.0	—	210
20	2.0	1.90	2.50	22.7	0.95	1.0	—	5.	1.0	—	275
24	2.0	2.1	3.00	26.9	1.05	1.0	2.5	5.	1.05	—	440
30	2.0	2.3	2.85	33.2	1.15	1.0	2.5	5.	1.15	48	640
36	2.0	2.5	4.00	39.1	1.25	1.25	2.5	5.	1.25	48	920
40	2.0	2.7	4.00	43.25	1.35	1.50	2.5	5.	1.50	54	1220
48	2.0	3.0	4.00	51.5	1.50	1.50	2.5	5.5	1.75	96	2050

REDUCERS.



No. 1.



No. 2.

DIMENSIONS IN INCHES.													WEIGHT
No.	a	b	c	d	e	r	y	l	t^1	t^2	CLASS	
1	4	3	2	7	9	2	2	20	0.45	0.40	B	55
1	6	4	3.3	7	10.7	3	3	23	0.50	0.45	B	75
1	8	6	3.8	7	10.2	4	4	23	0.55	0.50	B	110
1	10	6	6.0	10	12	5	5	30	0.60	0.50	B	155
1	10	8	4.6	10	12	5	6	28.6	0.60	0.55	B	180
1	12	6	8.0	10	12	6	6	32	0.65	0.50	B	185
1	12	8	6.6	10	12	6	6	30.6	0.65	0.55	B	210
1	12	10	4.8	10	12	6	6	28.8	0.65	0.60	B	240
2	16	10	20	8	8	—	—	36	0.75	0.60	B	285
2	16	12	20	8	8	—	—	36	0.75	0.65	B	310
2	20	12	26	8	8	—	—	42	0.85	0.65	B	450
2	20	16	26	8	8	—	—	42	0.85	0.75	B	530
2	24	16	26	8	8	—	—	42	0.94	0.75	B	630
2	24	20	26	8	8	—	—	42	0.94	0.85	B	720
2	30	20	26	8	8	—	—	42	1.10	0.85	B	900
2	30	24	26	8	8	—	—	42	1.10	0.94	B	1000
2	36	30	32	8	8	—	—	48	1.15	1.10	B	1530
2	36	30	32	8	8	—	—	48	1.04	0.93	A	1340
2	40	30	32	8	8	—	—	48	1.12	0.93	A	1480
2	40	36	32	8	8	—	—	48	1.12	1.04	A	1675
2	48	36	32	8	8	—	—	48	1.25	1.04	A	1980
2	48	40	32	8	8	—	—	48	1.25	1.12	A	2130
	•											

The designs are not claimed to be better than any others which may have been or can be made, but they are thought to be of as compact form and light weight as it is advisable to adopt.

The reducers and offsets have a bead cast back of the bell so that the bell can be cut off leaving a bead on the end of the casting. This plan has been adopted to avoid a multiplicity of patterns, but if desired the castings could be ordered without bells.

The design for Y branches is one which has been used in Boston for the past twenty years with the best of results. Y branches are apt to be deficient in strength, but I have never known of the failure of one of this design.

As to the limit of variation from the standard weights which should be allowed, it seems to me that a variation of 4 or 5 per cent. should be the requirement of our specifications.

There is another point I wish briefly to touch upon, a subject I spoke of a year ago, and that is the casting of a pipe bell up or bell down. At that time there seemed to be an opinion among a number of the members that it was a point of very little importance, and one gentleman advanced the idea that it was the province of the engineer to specify the kind of pipe wanted, and the province of the founder to make it in any way he saw fit. I only wish now to quote from a letter the opinion of Mr. George W. Whitman, who has been an inspector of pipes for many years, and whose opinion I consider of great value. In reply to an inquiry in regard to the question, he answers as follows: "I was under the impression that the bell-up or bell-down question had been finally settled. Of course, founders having no fixtures for casting pipes head down will argue that head up is just as good. But I have noticed that as soon as they have fixtures for head down work they generally acknowledge that that gives a much more solid and clean head, overcomes the liability of shrinkage cracks in the neck, gives a uniform size and depth of socket, and is in every way the best and easiest way to cast pipe."

Mr. Billings. I am moved to say this much in reply to the remarks of my friend Brackett, and that is that the letter which he has read from Mr. Whitman, as I interpret it bears out to some degree the position which I took a year ago, namely, that it is the pipe founders themselves who have settled the point as to what is the best method of casting pipe. I said at that time, I think, that all pipe founders agree, all founders of any sort of iron castings, that the better iron is found in the bottom of the blow, but I also said it was a subject for the founders to settle, and if they finally agreed they could get the pipe which the engineer wanted by casting it bell down, that was the way to do it, and that they were the ones to say whether it should be bell down or bell up. And Mr. Whitman appears to say that the founders have settled it for us by deciding that they can cast it bell down, and do so.

Mr. Brackett. It seems to me that with pipe contractors, as with contractors in general, there is likely to be a difference of opinion as to the way work should be done; and while one man may be ready to do it in the best way, another one for personal reasons may prefer to do it in some other way which may be cheaper but may not give the best results.

MR. NOYES. This question is one which has been of great interest to me for a number of years. It has been brought very largely to my attention from the claim of pipe founders, especially, as Mr. Brackett suggests, when they are not specially rigged for casting their pipe bell down, that the pipe comes out just as well exactly, and perhaps it is a little better, by being cast bell end up, rather than bell down. Wishing to be entirely conservative in my judgment in all these things, and placing confidence in the experience of the founders, I have endeavored to look into the matter very carefully; and from all the evidence I can get, either from personal observation or from conversation with inspectors who have given special attention to the question of the relative quality of pipe cast one way as against that cast the other way, I find by my own experience and observation, and it has been stated almost universally by the inspectors, that the better average pipe is obtained with the bells cast down; that with the bells cast up the area of the opening is less in proportion to the whole than it is with the spigot up; that the dirt or dross does not get out of the iron, and that a larger percentage of the bells, that is, a larger percentage of the pipe, are defective in the bells cast in that way.

During the past year, or within the last eighteen months, the matter has been under very considerable discussion, and the strongest kind of pressure has been brought by the founders to induce the engineer to admit the pipe cast bell up.

MR. ALLEN. I want to say that I think this matter of having standard special castings is a most excellent idea. It seems to me that there is nothing to be said against it. I should hope that it might be brought about that there would be a standard fixed, so that when ever we wanted a special casting of any form we could simply send to the founder and state what we want and have it sent, without special plans. I think very likely the society could have a great influence in bringing that about if they should take it upon their hands to do so, and I should think it had better be done.

MR. FULLER. My experience has been that pipes are more often cracked at the spigot end than at the bell end. I suppose, if it were necessary that there should be cracks at all, they had better be at that end. But it seems to me that there cannot be any doubt that it is better to cast the pipes with the bell ends down, and I judge from what I hear that that is becoming the uniform custom. I think that the pipe that we get from the manufacturers now-a-days is certainly of good quality, and if the trouble of uneven thickness could be avoided, it seems to me that there would not be much left to be desired in the matter of cast-iron pipe.

A DESCRIPTION OF THE HYDRAULIC LABORATORY OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

BY

PROF. DWIGHT PORTER.

[Read and Illustrated by Stereopticon, June 14th, 1893.]

This laboratory has been arranged and equipped upon an extensive scale for experimental researches and practical tests in hydraulics. The apparatus is used by the students of nearly all the engineering courses in regular laboratory exercises, during which they work in sections no larger than strictly necessary for conducting the particular experiment in hand. Such work is designed to give the students a practical demonstration of laws with which they have become familiar in a theoretical way only, to acquaint them with the appearance and behavior of certain standard forms of apparatus, and to teach them the methods and precautions commonly necessary in hydraulic experiments. The time allotted to any one variety of work is what seems sufficient fairly to attain the above ends, and no more, it not being proposed in class exercises to make the young men adepts, nor in general to achieve results in those exercises of especial scientific importance. In connection with thesis work, or the studies of post-graduate students, special apparatus is every year devised and installed, suited to original investigations and to the securing of results of permanent interest and value.

The space devoted to the hydraulic laboratory covers about 30 x 50 feet on each of the two lower floors of the engineering building. The general arrangement of pipes and apparatus on the second floor of the laboratory is shown by the plan (Figure 1), and the view (Figure 2). The primary source of water-supply is the city main, but it is rarely that draught is made directly upon this during an experiment, water being directly supplied from pumps, which in turn draw from a large receiving-pit sunk below the basement floor, the discharge from all experiments finding its way to the pit and thus being used over and over. Several pumps are in use—steam, rotary and centrifugal—supplying the different apparatus. In order to secure a more constant pressure than that from the pumps, for certain kinds of experiments, a ten-inch stand-pipe, shown in plan in Figure 1, eighty feet high, has been built, reaching to the top of the building. The supply to this from the pumps may be so regulated by valves and over-flows, conveniently arranged on each floor, that the head shall be kept at any desired point during an experiment, with a fluctuation of scarcely a hundredth of a foot. Many of the pieces of apparatus have been so arranged that they can be run at will under pressure either from the stand-pipe or directly from the pumps.

An important feature of the plant is a closed steel tank, five feet in diameter

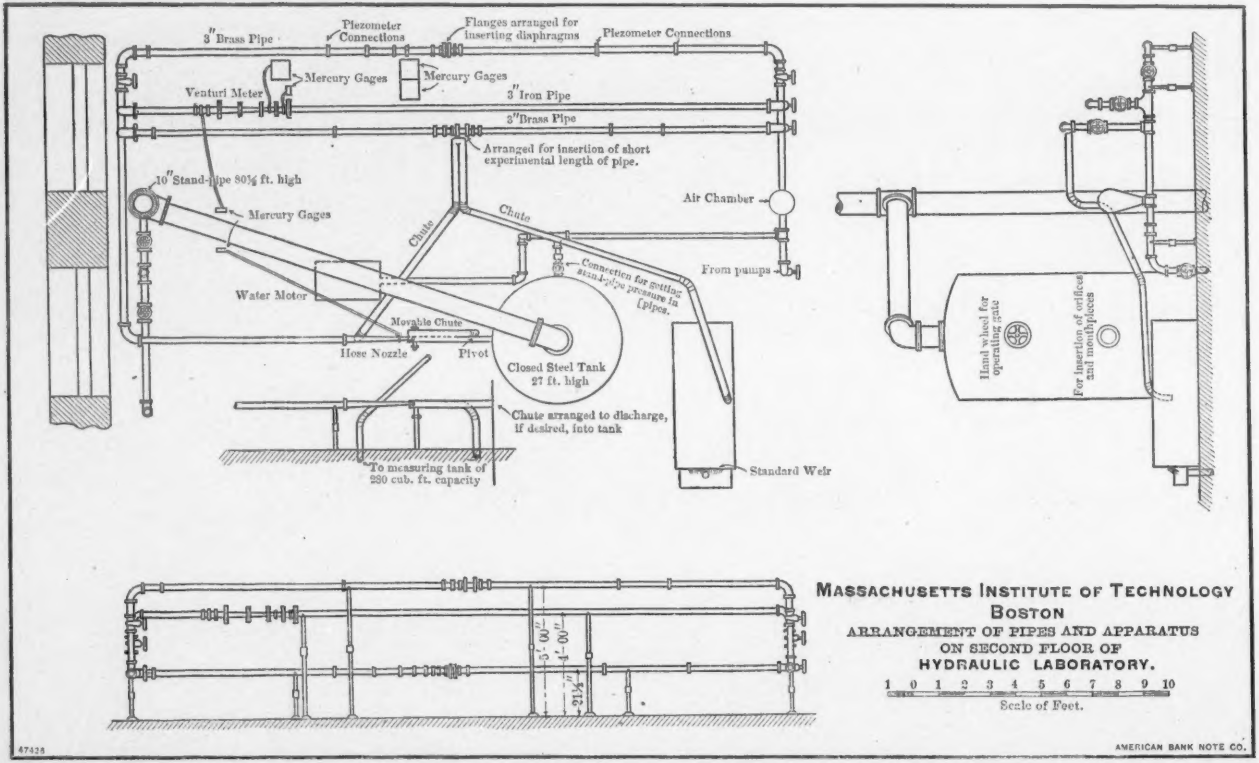


FIG. 1. Pipes and Apparatus on Second Floor of Hydraulic Laboratory.

and twenty-seven feet high (Figures 1, 2 and 4), extending from the basement floor upward through two stories. It is connected at top and at bottom with the stand-pipe previously mentioned, and at four points on each floor is arranged for the insertion of orifices, free or submerged, mouth-pieces and other fittings, and for connections with motors and experimental pipes. It is fitted with hydraulic gates so planned that an orifice, for example, may be quickly exchanged for another without the necessity of drawing down the water in the tank.

For certain experiments on the flow of water through pipes, three lines of three-inch pipe (Figures 1 and 2) have been erected. One of these is of iron, with a Venturi meter, shown on the right of the foreground of Figure 2, inserted in its course; the other two are of brass, very carefully made, with piezometer connections of approved form at sundry points. One of the brass pipes is arranged for the insertion of diaphragms with orifices of various sizes; and the other, for the insertion of short experimental pieces of pipe provided with side orifices, branches, or other devices. The discharge from the various pipe-lines passes finally through a hose-nozzle, with pressure-gauge connection to be used in determining the co-efficient of discharge. The nozzle discharges (Figure 1) into a movable double-chute, through one branch of which the flow may be wasted until it is desired to begin an experiment, when the other branch may instantly be thrown into the path of the jet, and the water directed through the floor into a measuring-tank beneath.

For delicate observations upon the velocity at any given point in flowing water, the laboratory contains three different instruments (Figure 3) embodying the principle of the Pitot tube. Two of these, for use, respectively, in jets from nozzles and in streams flowing under pressure through pipes, are the property of Mr. John R. Freeman, by whom they have kindly been placed at the command of the Institute. The third, for jets from standard orifices, has been designed especially to use on the large tank, which has been described, and one in use is shown by Figure 4. In each case, the pressure of the flowing water due to its velocity is transmitted through a minute orifice and a connecting tube to a mercury gauge, the reading of which indicates the velocity at the tip of the tube. A simple attachment to the last-mentioned of these devices has permitted measuring the shape of the jet and the size of the contracted vein with the greatest nicety.

For measuring the quantity of water discharged during experiments, the common method employed is that of weighing, the temperature of the water being at the same time observed. Thus, in determining the co-efficient of discharge of standard orifices, the flow from the orifice passes into a large cask, with ample discharge-pipe and quick-acting valve at the bottom, and thence into another and similar cask underneath, resting directly upon scales. The upper cask serves for temporary storage while the contents of the lower one are being weighed and discharged. By this means, with casks of moderate size, it is not difficult to weigh continuously at the rate of 40,000 or 50,000 pounds of water per hour. Again, the discharge from experiments on the

second floor may be diverted through chutes to any one of several measuring devices on the floor below. One of the most important of these is a cylindrical steel tank, six feet in diameter and ten feet high, capable of holding some 280 cubic feet of water. This tank is conveniently placed for drawing off and weighing the contents, and is by this means calibrated. In order to determine the quantity discharged into the tank in any experiment, it is then necessary only to read a glass-gauge attached to the tank and provided with sliding sight and vernier. For more indirect determinations of quantities of water, the laboratory contains a number of weirs of different lengths, up to four feet, a calibrated orifice tank, Venturi and other water-meters, nozzles and standard orifices.

The pieces of apparatus which have been mentioned will suggest to the mind a great variety of experimental work to which they are suited, and to much of which they have actually been applied. The laboratory further contains a Pelton water-motor, a small Swain turbine, a Douglas hydraulic ram and a variety of dynamometers, mercury-gauges, piezometer fittings, etc. Figure 5 is a view of a Swain turbine being tested by students. There have also been placed in the laboratory a large number of finely-constructed orifices and metal pieces of sundry descriptions, which were used many years ago by Uriah Boyden and James B. Francis in their famous experimental work at Lowell.

The laboratory has been designed with a view to extensive further developments, important advances in which are likely to be made every year. It has been steadily taxed to its utmost capacity, both for regular class exercises and for thesis work, and fully commends itself as a substantial aid in engineering education.

HYDRAULIC FIELD-WORK.

In connection with the laboratory, it seems not out of place to mention the course in Hydraulic Field-Work, which is similar in nature to work in the laboratory, but is on a larger scale. It consists in measuring the flow of some stream by means of current-meters and floats. The civil engineering department is equipped with Fteley, Ellis, and Ritchie-Haskell current-meters, and with tubes, Ellis sub-surface and other forms of floats. Hydraulic measurements constitute an important part of the summer-school work, and students not attending that school receive their practice in the early part of the fall term in the vicinity of Boston, exercises being arranged so that, for a time, one day of the week is entirely free for this work. For the term work, measurements have been made, at various times, of the flow of the Charles and Merrimac rivers, and of the hydraulic canals at Lowell and Lawrence; while at the summer-school the Connecticut, Delaware and Schoharie rivers have been gauged. These streams have given a range in volume from 50 to 8,000 or 10,000 cubic feet per second, and a great variety of conditions as regards width, depth, velocity of current, and methods of conducting the measurements. The observations made in the field are worked up in the drawing-room, diagrams being constructed for the cross-sections and velocity curves, and the computations being based upon them.

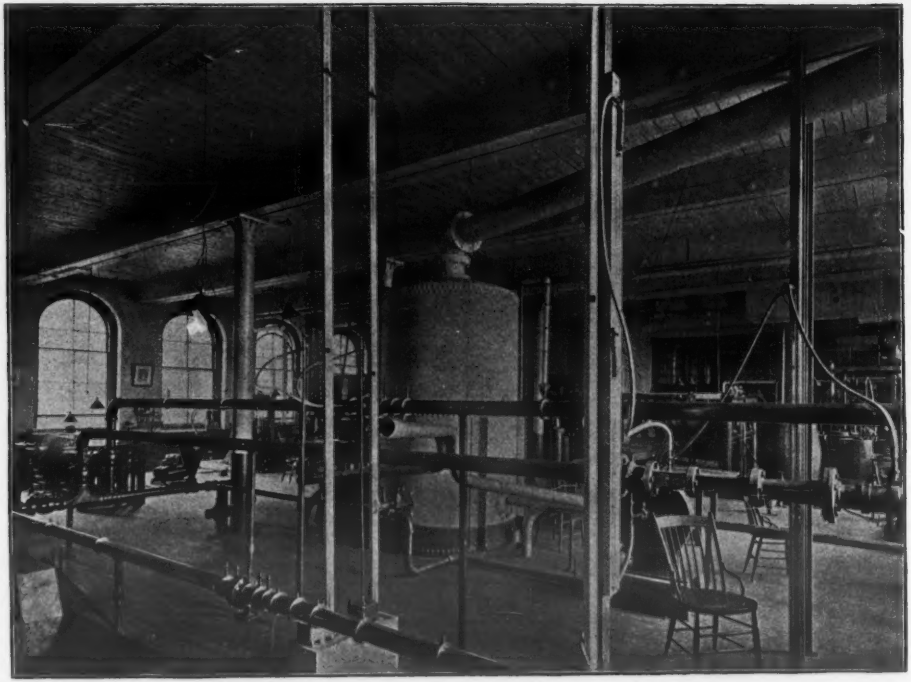


Fig 2. View of Second Floor of Hydraulic Laboratory.

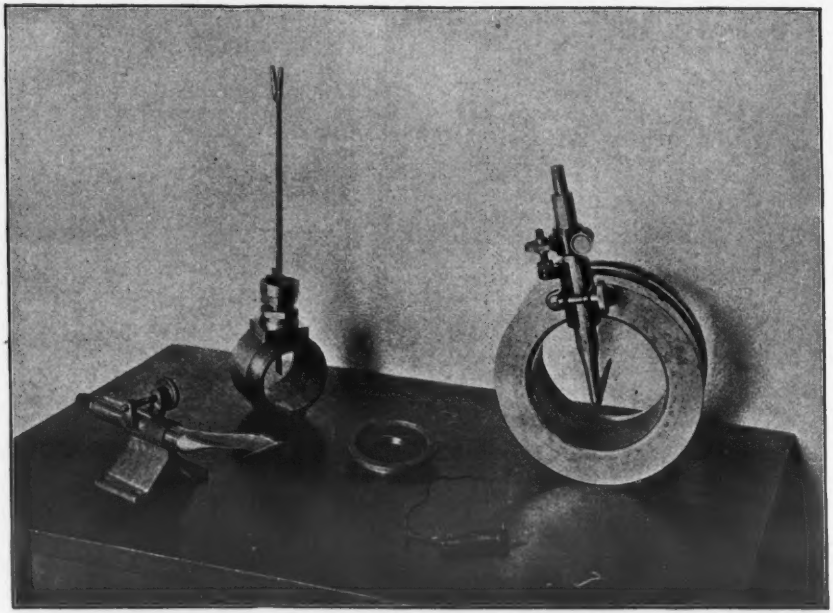
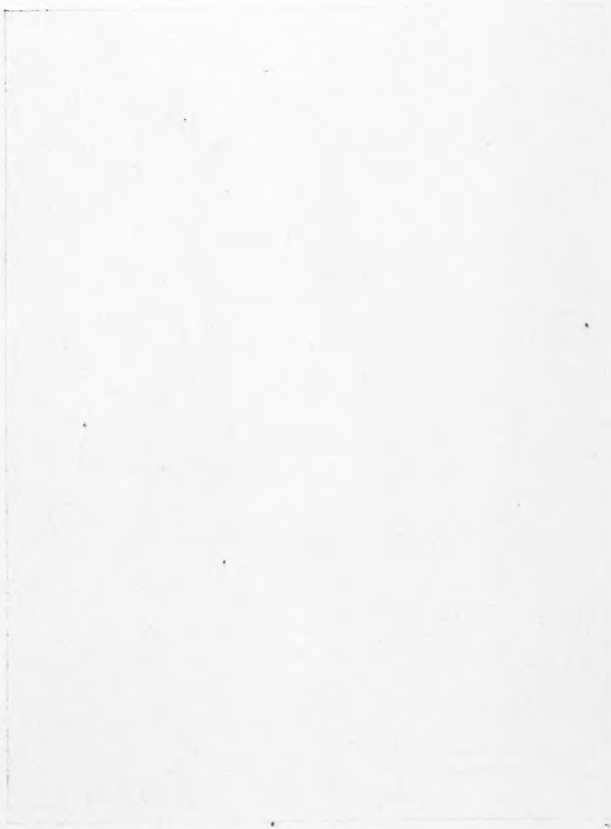


FIG. 3. Forms of Pitot Tubes Used in Experiments on the Velocity in Flowing Water.



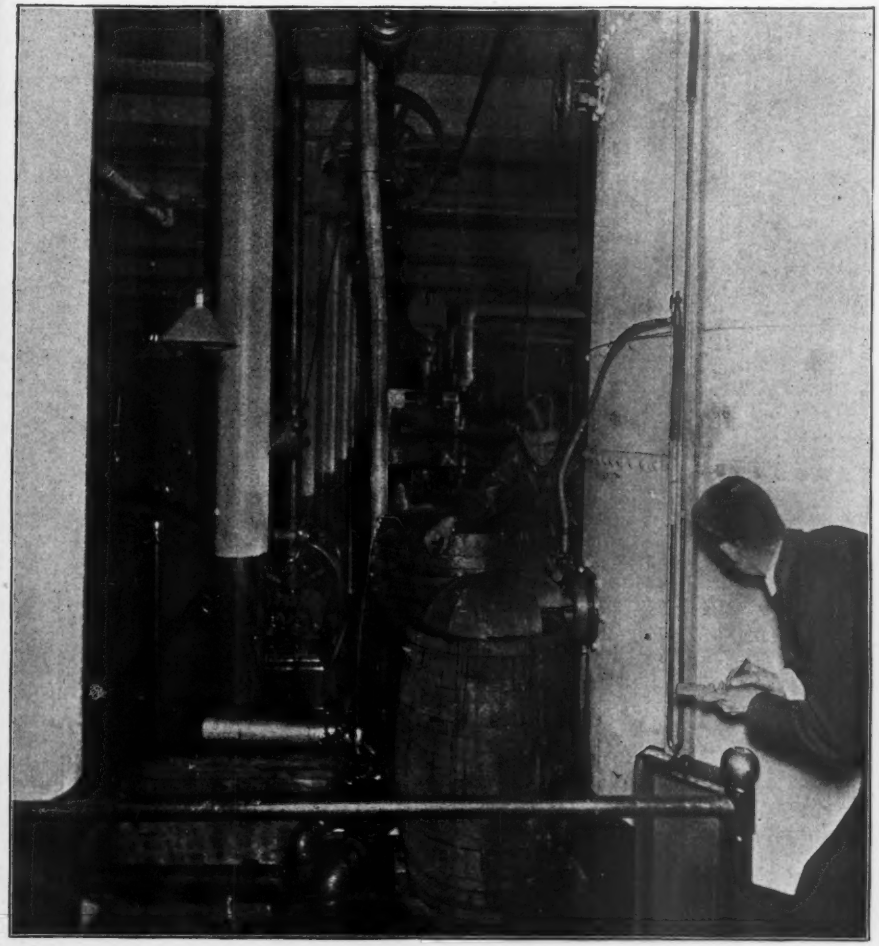


FIG. 4. Studying Variations in Velocity in a Jet from a Standard Orifice by Means of a Pitot Tube.

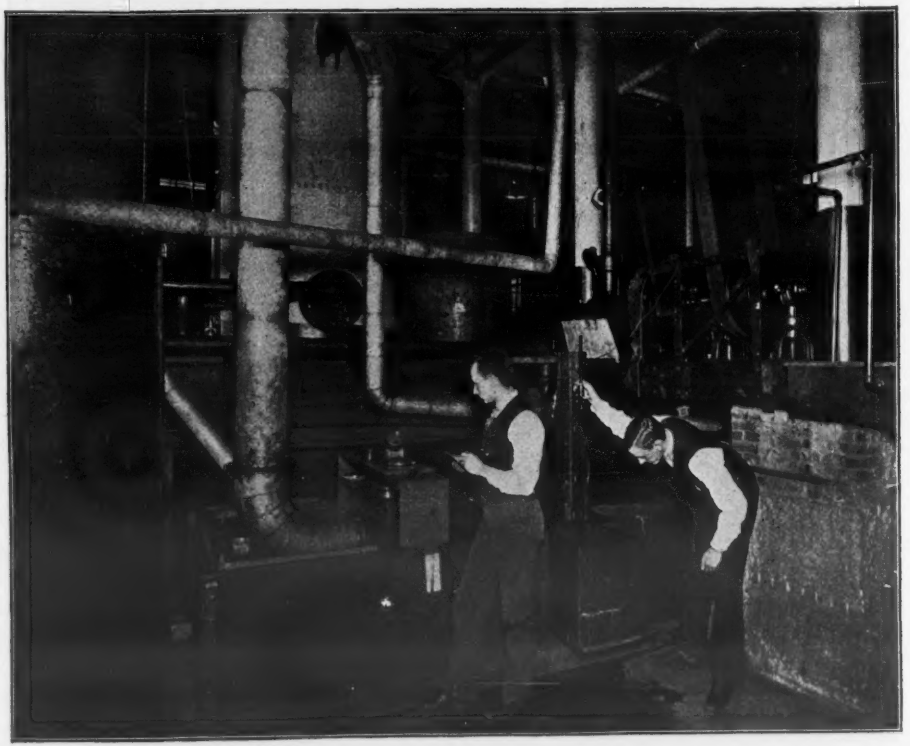


FIG. 5. Students Testing a Swain Turbine.

RECENT PRACTICE IN PUMPING ENGINES.

BY

F. W. DEAN, Mechanical Engineer, Boston, Mass.

[Read and illustrated by Stereopticon, June, 15, 1893.]

The development of pumping engines is a subject of great fascination. It seems strange to us that the Cornish engine should have reached such a state of perfection before the middle of this century, as to give a duty of 120,000,000 ft. lbs. per 100 lbs. of coal, but there seems to be no doubt that this was accomplished in 1840 at Fowey Consols Mines in Cornwall, by an engine with a cylinder 80 in $\times$ 10$\frac{1}{2}$ ft. and carrying a net pressure of 12.57 lbs. of steam per sq. in. This high rate of duty was brought about by using the steam expansively, by using steam jackets well protected, by an ingenious arrangement of valves which prevented the condenser temperature from extending to the steam side of the piston, adjacent cylinder heads and clearances, by compressing the steam to the initial pressure, by wire drawing and somewhat super-heating the working steam and causing the initial pressure and temperature to be considerably below those in the jacket, and thus almost wholly preventing condensation. The efficiency of the jacket was increased by the slowness of the return stroke of the steam piston, and by a pause of nearly a quarter of a minute between the completion of this stroke and the beginning of the steam stroke. The steam stroke was made with astonishing rapidity for such ponderous moving parts, amounting in cases to a rate of 500 feet a minute, and thus minimizing condensation.

The most economical performances of these engines occurred when they were new and under-worked. When the mines grew deeper and the steam worked less expansively, the duty diminished. The engine that once gave 120 millions duty, two years afterwards gave 77 millions.

The principle of expansion and the importance of diminishing condensation in steam cylinders were well understood in those days, the former having been thought out in 1769 and the steam-jacket invented in 1763, both by James Watt.

The average annual duty of Cornish engines in 1840 was about 55,000,000 ft. lbs.

Previous to 1873 the usual duty of pumping-engines in this country was about 60,000,000 ft. lbs. per 100 lbs. of coal, but in July, 1873, this time-honored record was broken by the so-called Morris engine at Lowell, Mass. This is a compound vertical engine of the Simpson type of 5,000,000 gals. capacity having both cylinders under one end of the beam and the pump and fly-wheel under the other. Steam enters the high-pressure cylinder from the boiler and at the completion of the stroke flows into the opposite end of the low-pressure cylinder, the steam flowing from one to the other during the whole stroke.

In July, 1873, a board consisting of Messrs. Hoadley, Francis and Worthen obtained a duty from this engine of 93,002,272 ft. lbs. per 100 lbs. of coal.

About this time the Worthington horizontal compound duplex pumping-engine was being introduced with great satisfaction and gave a duty of about 60,000,000 ft. lbs. per 100 lbs. of coal. The first engine of this type was built for the Charlestown, Mass., Water Works and was erected in 1864. A duplicate was there erected in 1866. The cylinders were 25 in. and 43 in. by 48 in. stroke. The pump-plungers were 22 in. in diameter, and the delivery-pipe 30 in. in diameter. The engines have been in service ever since, and are at work at present. This is a remarkable record, extending nearly 30 years.

A distinct impulse was given to high-class pumping-machinery by Mr. E. D. Leavitt, whose engine at Lynn was tested in Dec., 1873. This was an improvement on the Morris engine at Lowell in consequence of the pistons moving in opposite directions, and thus diminishing the length and volume of the passages between the cylinders. These features were accomplished by connecting the pistons to opposite ends of the beam, and thus permitting the high-pressure exhaust to pass to the nearest end of the low-pressure cylinder. The virtues of this arrangement were still farther brought out by inclining the cylinders so as to bring them as near together as possible.

The superiority of the Lynn over the Lowell engine did not end here, however. This engine had a type of steam-valve that gave a large port opening with small clearance between the piston at the end of the stroke and the valve-face and thus diminished losses to which the Lowell engine was subject. Moreover, the Lynn valves do not, like those at Lowell, leak with age.

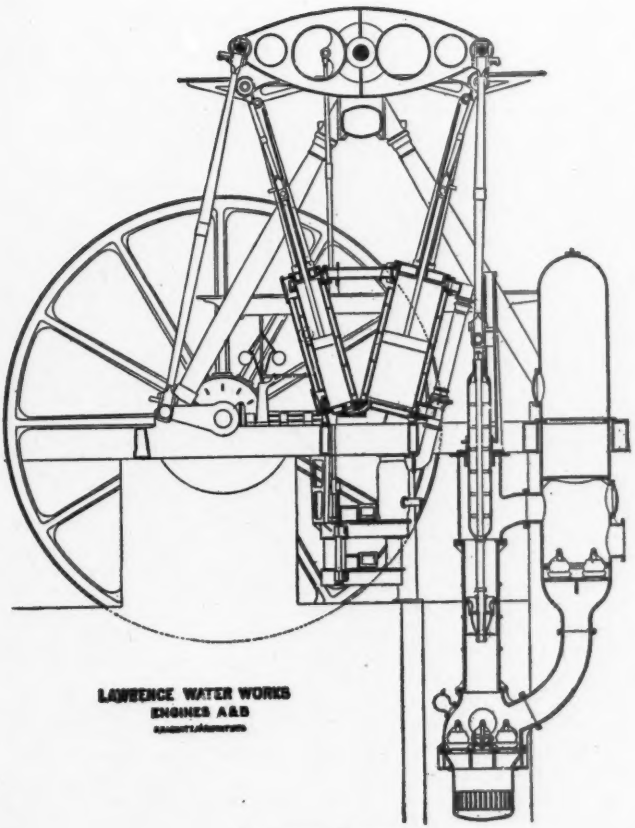
The whole effect of the Lynn design was to diminish condensation, loss of work between the cylinders and loss of steam in the clearances of the low-pressure cylinder by discharging it to the condenser. This engine was tested by Messrs. Worthen, Hoadley, Kirkwood, Hermany and Davis, and gave a duty of 103,923,215 ft. lbs. per 100 lbs. of coal, being the highest duty ever recorded in the United States up to that time. With it began an era of high duties in this country, which have ever been increasing, until it seems that there is but little more to be accomplished.

I shall dwell a little upon the Leavitt engines because in them now are to be found all those features that promote economy in steam-engines, and their development is interesting.

The Lynn engine was followed by those at Lawrence, which are of the same type, but larger. They were carried out better in detail at the steam end, but chiefly on account of great pump-friction the duty was lower, being only 96,186,979 ft. lbs. per 100 lbs. of coal. The official test was made by Messrs. Worthen, Hoadley and Davis, on May 2–6, 1876.

Mr. R. H. Buel tested these engines in July, 1879, after some changes had been made in the pumps and obtained a duty of 111,548,925 ft. lbs. per 100 lbs. of coal. A portion of the improvement was caused by better boiler performance.

Mr. Leavitt did not repeat this design, having seen the advantages of in-



Lawrence Engine.

verting the engine. He then placed the cylinders upon the tops of columns, the beam in pedestals in the bed-plate beneath and the main shaft in pedestals at one end of the bed-plate.

Two pumps instead of one, and a great many small pump-valves instead of a few large ones were used. The cylinders were placed as near together as possible, but for simplicity only the high-pressure cylinder was inclined.

By this design the economy of steam obtained at Lynn and Lawrence was realized, greater stability was obtained, shorter steam and pump connections were practicable, and two pumps could be used with great convenience. Moreover, most of the parts were more accessible than in the Lynn type.

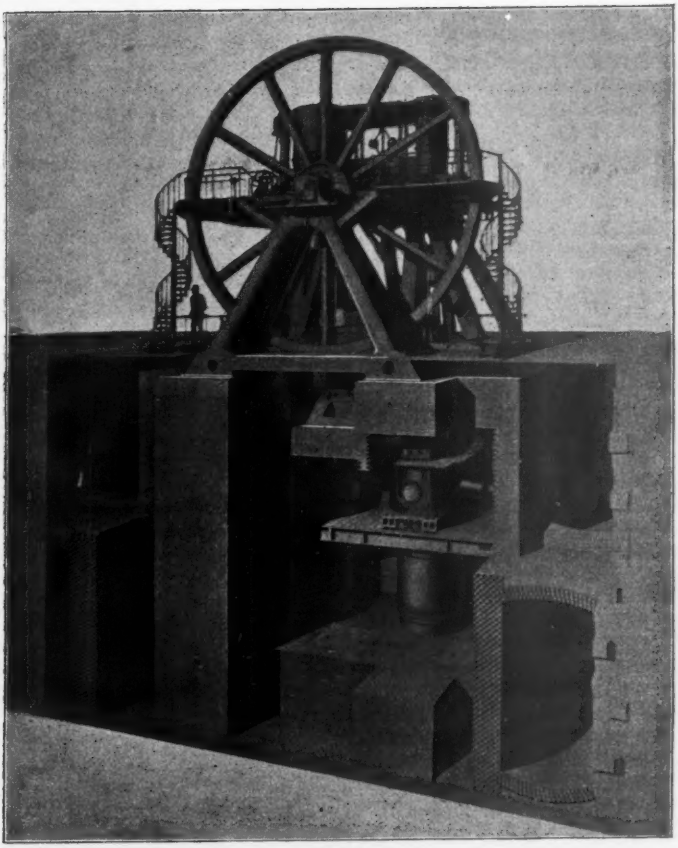
The inverted type just described is best illustrated by the pumping-engine "Ontario" at the Calumet & Hecla Mine. It has a vertical low-pressure cylinder 36 inches in diameter, and an inclined high-pressure cylinder 17½ inches in diameter, the stroke of both being 5 ft., the maximum revolutions per minute giving a plunger speed of 330 feet per minute. This engine runs 24 hours a day 6 days in the week and is one of the the smoothest and best working pumping-engines in the country. It has been speeded up several times in order to keep up with the demand for water and thus far runs better with the higher speed. It has 72 suction and the same number of discharge-valves, both 5¼ inches in diameter and ⅝ inches maximum lift. The pumps have differential plungers, each single acting on the suction, and double on the discharge.

The next Leavitt engines bearing new features are the Boston Sewerage Engines. While they resemble the Ontario, it will be noticed that both cylinders are vertical, Mr. Leavitt having by that time seen that by placing a cut-off-valve on the low-pressure cylinder there was no longer need of keeping the cylinders near together. By a proper determination of the point of cut-off in this cylinder most of the loss of work between the cylinders caused by unresisted expansion or drop is done away with.

Here again is seen for the first time a re-heating receiver between the cylinders for the purpose of drying the steam exhausted from the high-pressure cylinder. The re-heating is done by steam of boiler-pressure within many small brass tubes, around the outside of which the exhaust steam plays.

The cylinders of this engine are too large, the engine having been designed for a greater lift than that finally adopted, but notwithstanding the great expansion of the steam, and the slow speed, the engines use but 14 lbs. of steam per indicated horse-power per hour. The number of expansions with 96 lbs. of steam at the engine was 22, and the number of evolutions per minute about 13⅓ corresponding to 240 feet of piston-speed per minute. Now this economy, notwithstanding unfavorable conditions, is without doubt due to steam-jackets and the re-heater.

The next Leavitt pumping-engine that deserves attention is the 16,000,000-gallon engine designed for the Louisville Water Co. of Louisville, Ky. This engine has steam-cylinders 27 in. and 54 in. by 10 feet stroke, and is to run 18 evolutions per minute giving a steam-piston speed of 360 ft. per minute. The engine, like the Ontario and Sewerage Engines, is inverted, with the beam under the cylinders, but unlike the Sewerage and like the Ontario has the fly-



Boston Sewage Engine.

wheel out at the end of the bed-plate. The plungers are two in number, are of the differential type and are connected to the beam at points between the ends and centre of the beam, so as to give a stroke of 7 ft. 6 in. to the plungers. This gives a plunger-speed of 270 ft. per minute. This engine is to work with 140 lbs. of steam by the gauge, and ought, if the jackets and re-heaters are as efficient as anticipated, to use somewhat less than 14 lbs. of steam per horse-power per hour.

This engine is remarkable in having very long pump-chambers on account of its location. The Ohio River water-level at Louisville varies some 50 ft., so that the engine proper is placed high and the pump reaches to the low water-level. Each pump is 61 feet long, 8 ft. inside diameter, and each plunger is 40 ft. long. There will be 143 suction-valves and 124 delivery-valves to each pump.

This engine is not only remarkable for the height of the pumps, but also for the weight of all the parts, it being the determination of the Water Co. to prevent breakage if possible. The total weight of the engine is 800 tons.

The Louisville engine is the last Leavitt compound pumping-engine built, and represents its highest development.

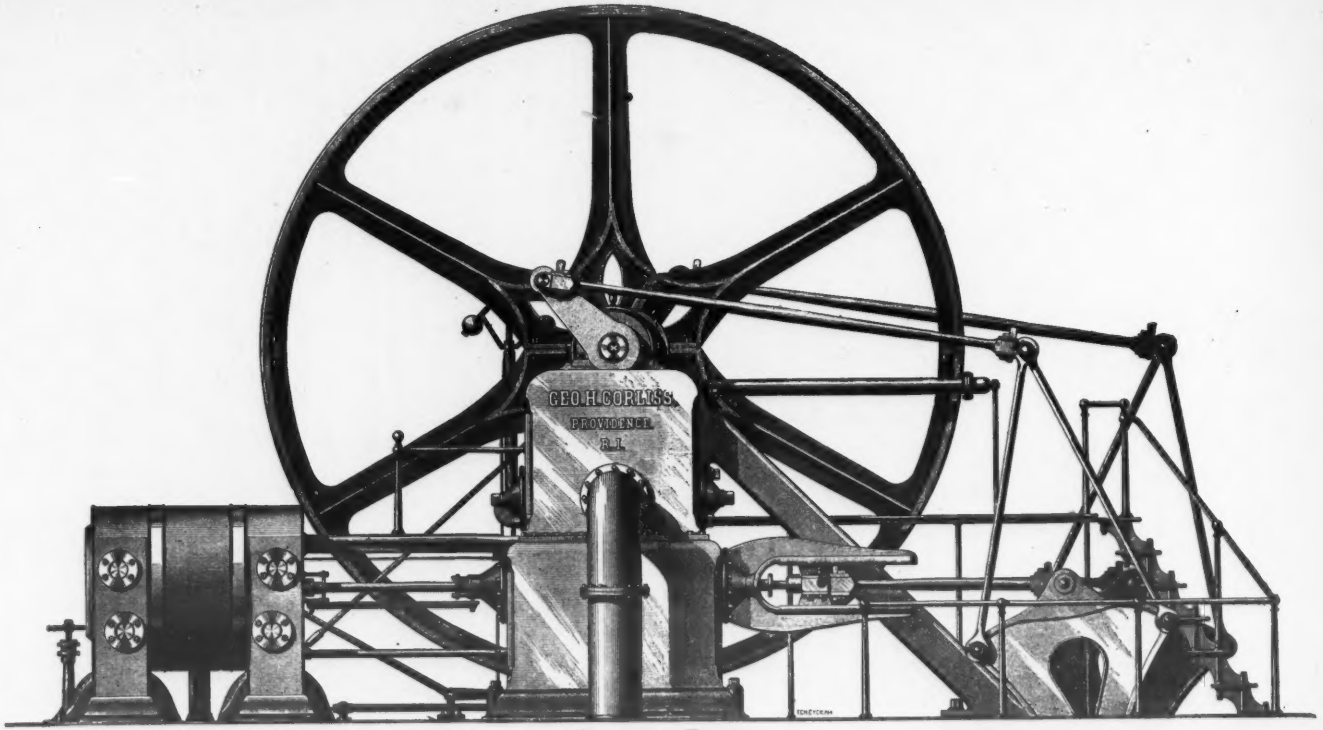
This was followed by a 60,000,000-gallons triple-expansion engine to carry 185 lbs. of steam, for the Calumet & Hecla Mines, but of this I am not at liberty to speak.

Following this came the new engine for the Chestnut Hill Pumping Station for the City of Boston, which is of 20,000,000 gallons capacity. This is a triple-expansion engine having cylinders 13.7 in. 24⅝ in. and 39 in. × 6 ft. stroke, and has three plungers 17½ in. diam. by 4 ft. stroke. The engine will make 50 revolutions per minute corresponding to a steam-piston speed of 600 ft. per minute and pump-plunger speed of 480 ft. per minute. The steam-pressure will be 185 lbs. by the gauge, giving about 30 expansions. The steam consumption ought to be below 12 lbs. per horse-power per hour.

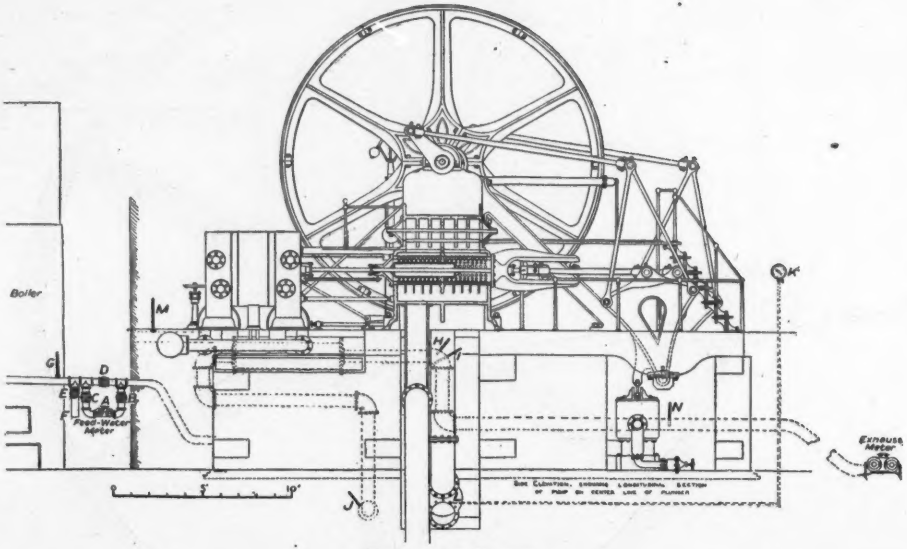
During the development of the Leavitt pumping-engine, Mr. George H. Corliss was giving much thought to the matter, and built two experimental engines, which he worked in his shops at Providence. His Pawtucket engine was started on Jan. 30, 1878, and tested in October, 1878, by Walter H. Sears and Isaac N. Scott. The duty per 100 lbs. of coal during a 24 hours' test was 133,522,060 ft. lbs., which is the highest duty ever recorded for a compound engine.

The Pawtucket is a cross-compound having cylinders 15 and 30 x 30, and runs 49 revolutions per minute. The pump-plungers, two in number, double-acting, at 10.52 in. diameter and 30 in. stroke. The steam-piston and pump-plunger speed is 245 ft. per minute.

This engine is remarkable in many particulars. It has beams that give a crank throw double that of the piston travel, the beams being built up partly of wrought-iron links of very light and lofty construction. It has not only surpassed all records of compound-engines in this country for economy, but is remarkable for having cost virtually nothing for repairs. This immunity from repairs is said to be due to the elasticity of its construction and the resulting diminution of shocks. It is also remarkable for having a great num-



PAWTUCKET ENGINE.



PAWTUCKET ENGINE.

ber of pump-valves, $2\frac{1}{4}$ in. in diameter with a lift of $\frac{1}{4}$ in. The aggregate area of these valves is equal to the area of the cross-section of the plunger. They are made of bronze annular discs $\frac{1}{32}$ in. thick, and while they slam on their seats they are so light and move so little that they neither injure themselves nor their seats.

This engine was tested by Prof. J. E. Denton and gave a duty of 127,350,000 ft. lbs. per 100 lbs. of bituminous coal and would have given 136,000,000 ft. lbs. if the boilers had evaporated 10 lbs. of water per pound of coal. The steam used per horse-power per hour was about $13\frac{3}{4}$ lbs. The cylinders are jacketed, but careful experiments show that the jackets have not in this case the usual value, saving only some 2 or 3 per cent. of steam. A source of economy of the engine is the location of a re-heater in the smoke-flue, through which the condensation from the receiver is passed and then returned to the low-pressure cylinder.

In 1881 Mr. Corliss erected a pair of compound vertical-beam pumping-engines at the Pettacouset pumping-station at Providence of 9,000,000 gallons capacity, guaranteed to give a continuous duty of 100,000,000 ft. lbs. per 100 lbs. of coal. The engines have one high-pressure cylinder under one beam 18 in. diam. and one low-pressure under the other beam 36 in. diameter, both strokes being 6 ft. Each engine works two 19 in. plungers with 36 in. stroke. The pumps have valves like those in the Pawtucket engine. This engine gave an average duty for one year of 106,048,000 ft. lbs., and on a test by Samuel M. Gray, during six days of about 12 hours each, including banking coal, a duty of 113,271,000 ft. lbs. per 100 lbs. of coal. The estimated duty of the engine, with banking coal deducted, was 138,035,000 ft. lbs.

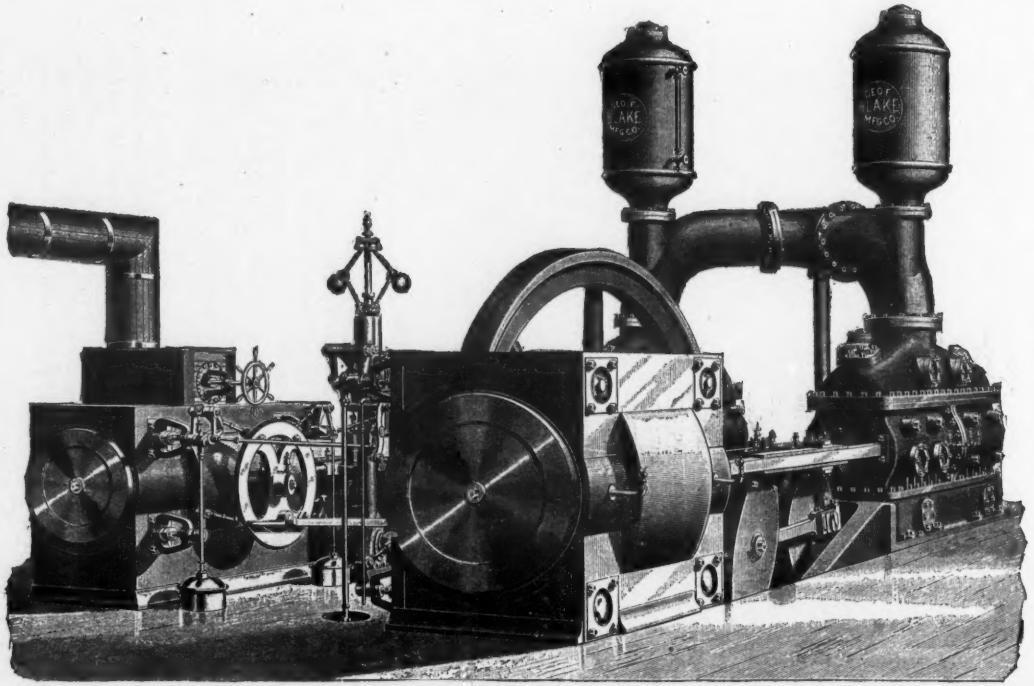
A second engine was put in at Pawtucket by Mr. Corliss, being in most respects like the first engine, and this ended Mr. Corliss' work in this kind of engineering.

Among the fly-wheel pumping-engines deserving great attention both on account of the merit of the arrangement of the cylinders and the great number in use, is the Gaskell engine. This accomplishes in a very perfect way what was sought by the first Leavitt design, viz.: opposite movements of high and low-pressure pistons and direct steam-passages from one cylinder to the other. This engine ought to be unsurpassed as an economical steam-user by any engine without a re-heater and a cut-off on the low-pressure cylinder. The usual amount of feed-water used by it per hour per horse-power is about 17 lbs., although occasionally it is less. At Philadelphia the amount reported is 14.94 lbs., or practically 15 lbs.

The pump-end of the Gaskell engine is distinguished by the use of numerous small rubber-faced valves, over openings $2\frac{1}{4}$ inches diameter, and lifting $\frac{5}{16}$ inch. The valves are exceedingly simple and are within cages screwed into the valve-plates of the pumps.

The engine is slow-running and has a small aggregate area of valve-opening, but there seems to be no reason why it should not run fast if ample valve and water-way area is given.

The usual duty of the Gaskell engine on trials appears to be 105,000,000 ft. lbs. per 100 lbs. of coal.



BLAKE ENGINE.

A newly-introduced compound fly-wheel pumping-engine is the Blake engine, of which six have been built. This engine has one high and one low-pressure cylinder and a Corliss valve-gear controlled by a governor. The gear is so made as to give a range of cut-off from 0 to $\frac{3}{4}$ stroke. It has two cranks at right angles to each other, a cut-off on the low-pressure cylinder and a re-heating receiver. It has all the usual means of economy and, as might have been expected, uses about 14 lbs. of feed-water per horse-power per hour.

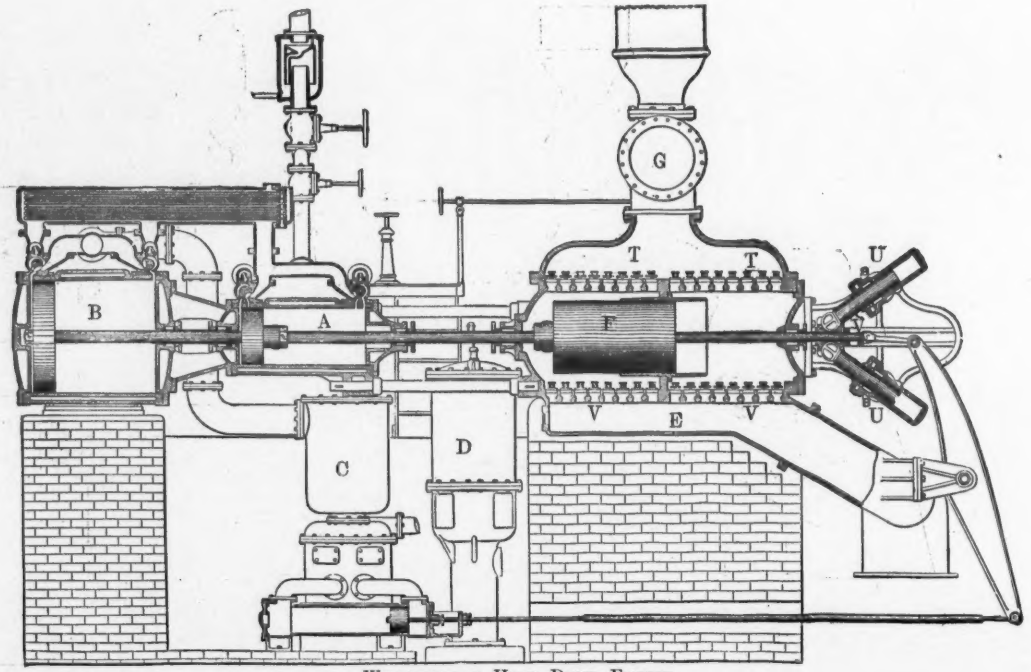
The pump-end has many small valves with a small lift, and aggregate opening of over $1\frac{1}{2}$ times the plunger-area. The usual duty to be expected is about 120,000,000.

One of the most interesting, important and scientific improvements in pumping-engines is that of elevating the direct-acting pumping-engine to the position of being a high-duty engine. The writer believes that there were several almost simultaneous inventions to accomplish this end, but that with which we are familiar is the high-duty pumping-engine manufactured by H. R. Worthington. The Worthington compound duplex pumping-engine, until this improvement was made, was a low-duty engine, because it could expand the steam only an amount due to the cylinder ratio, because it had large clearances, and could not compress steam in them up to the initial pressure. By means of the high-duty attachment and a change in the valve-gear most of these defects are eliminated, and the great advantage is gained that the steam can be cut off at any desirable point, and any degree of expansion obtained. There are two sets of valves to each cylinder, two for admission and exhaust and two for cut-off. The admission-valves of the cylinders on one side of the engine are operated by the machinery of the other side, while the cut-off valves are operated by the same side. This enables the peculiar relative motion of the two sides to be retained and still makes it easy to secure a cut-off at any point.

In any pumping-engine the resistance on the plungers is nearly constant, but if the steam is cut off the propelling effort so quickly diminishes that the plungers would stop unless a fly-wheel or some equivalent device should carry them on. The high-duty attachment accomplishes this in virtue of having plungers which have upon them pressure from the force-main augmented by a special accumulator. During the first half of the stroke of the engine these plungers are forced in by the surplus steam-pressure, and during the last half the accumulator pressure forces them out and completes the stroke, and thus fully compensates for the low steam-pressure due to the early cut-off, and resulting expansion.

The Worthington high-duty compound-engine appears to use about $16\frac{1}{4}$ lbs. of steam per horse-power per hour, and therefore uses $\frac{16.25}{14} = 1.16$ times as much steam as a good fly-wheel engine. It would, therefore, in general, give a duty of about 106,000,000 ft. lbs. per 100 lbs. of coal.

It would be interesting to inquire why this engine is not as economical as good fly-wheel engines. The writer has not had time to investigate this fully, but an inspection of the cards, and an examination of the engine shows that there is not, and cannot be a closure of the exhaust-valves early enough to



WORTHINGTON HIGH DUTY ENGINE.

compress the steam in the clearances, up to initial pressure, in either cylinder. If this were attempted the compensating cylinders would not have pressure enough to complete the stroke. If the stroke is not completed the clearance is increased with the attendant loss. The engine has the important features of a cut-off on the low-pressure cylinder and a re-heater.

The last engine that I shall consider is that of which a specialty is made by The Edward P. Allis Co. of Milwaukee, Wis. It is a vertical three-crank and three-pump triple-expansion engine with cranks 120° apart. The pumps are of the single-acting outside packed plunger-type making their strokes at equal intervals of the revolution and thus giving a steady flow of water. The steam-cylinders have the Corliss type of valve-gear, although I believe that in a few cases a single beat poppet-valve has been applied to the heads of the low-pressure cylinders for the purpose of reducing the clearance and thus diminishing the waste to the condenser. The engines are also provided with steam-jackets, and two re-heaters, one between each two cylinders. There is a variable cut-off on each cylinder, that on the high-pressure being under the control of a centrifugal governor. In a general way the engine is provided with all essential features for economy, and the performance must depend upon whether the designer has made the most of his opportunities.

Attention was called to this type and make of engine by the remarkable performance of the first one at Milwaukee, which was phenomenal in consequence of the low-pressure of steam used, viz.: 80 lbs. by gauge, and the ordinary rate of speed of 25½ revolutions per minute. The amount of feed-water used per indicated horse-power per hour was 13.84 lbs., and the duty per 100 lbs. of coal was 129,403,204 ft. lbs.

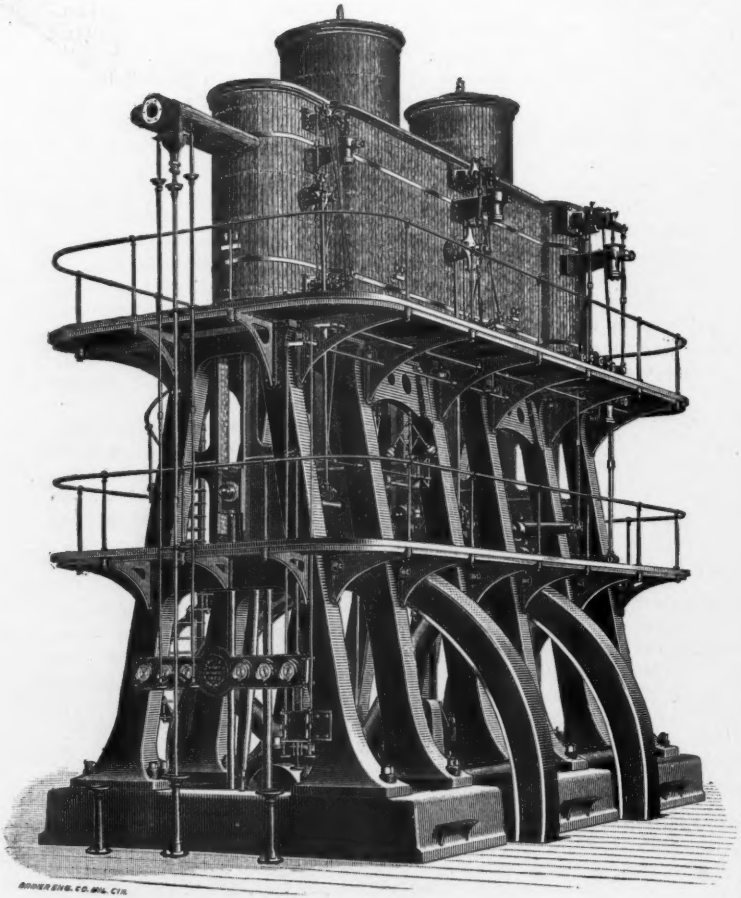
At St. Paul a similar engine gave a duty of 113,611,037 ft. lbs. with 90 lbs. of steam when running at 30.4 revolutions per minute.

At the Harrison Street Pumping Station, Chicago, this type of engine gave a duty on an eight hours' test of 140,416,679 ft. lbs. with 1,000 lbs. of steam, and used 12.675 lbs. of feed-water per indicated horse-power per hour. The steam-gauge pressure was 125 lbs. per sq. in., and the average speed 16⅔ revolutions per minute.

The latest test of this type of engine was made by Prof. Carpenter of Cornell University at Milwaukee on March 25 and 26, 1893.

The engine has cylinders 28, 48 and 74×60, and three single-acting plungers 32 in. × 60 in. stroke, uses steam of 120 lbs. pressure by the gauge, and makes 20⅓ revolutions per minute. The capacity is 18,000,000 gallons per day against a total head of 161.845 ft.

The duty per	100 lbs. of	dry coal was	143,306,470 ft. lbs.
" " "	1,000 " "	feed-water was	152,448,000 " "
" " "	1,000,000 "	British heat units was	137,656,000 " "
" indicated horse-power was			573.87
" friction " "		"	52.91
" " " "		per cent	9.22
" dry steam used per indicated horse-power per hour was			11.678 lbs.
British thermal units per indicated horse-power per hour			217.6



ALLIS TRIPLE EXPANSION ENGINE.

The amount of steam per hour per horse-power by this engine is nearly unequaled, if not quite, although it is said that Sulzer engines in Europe have used less steam, and that a Willans engine in London has used 11 lbs. of steam while being tested with every care to promote economy.

The clearances of the Allis engine last described are remarkably small, being as follows:

High-pressure cylinder	$1\frac{4}{10}$ per cent.
Intermediate	$1\frac{5}{10}$ " "
Low-pressure	$0\frac{777}{1000}$ " "

The piston and plunger speeds were 203⅓ ft. per minute.

I have dwelt upon this type of engine because there are comparatively few of them in use and because they show what a triple-expansion engine can do. They are also interesting because they have used low steam-pressures. The triple-engine has the important advantage of more uniform pressures on bearings, and is therefore steady-running and less likely to heat its bearings than the double-expansion or simple engine.

Here I may properly refer to the importance of a governor to a pumping-engine, for with it the engine will come to a rest if a water-main bursts. In the case of the Worthington high-duty engine such a catastrophe will stop the engine by removing the pressure from the accumulator, and compensating cylinders, and thus deprive them of power to complete the stroke. The engine consequently stops.

Having now considered the prominent types of pumping-engines it is important to discuss the essentials to economy, and what we have to hope for in future. To assist in this I here tabulate the usual amounts of steam used per hour per horse-power by the various types, all having cut-off-valves on the high-cylinder and all steam-jacketed.

	Relative Value.
1. Compound fly-wheel without cut-off on low-pressure cylinder, and short steam-passages, lbs. per I. H. P. per hour.....17 lbs.	0.735
2. Compound-duplex direct-acting with cut-off on low-pressure cylinder, and re-heater.....16¼ lbs.	0.769
3. Compound fly-wheel with cut-off on low-pressure cylinder, and re-heater.....14 lbs.	0.893
4. Triple-expansion fly-wheel with cut-offs on intermediate and low-pressure cylinders and two re-heaters.....12½ lbs.	1.

It is well-known that the greatest obstacle in the way of economizing steam is the prevention of condensation in the cylinders, and it is now well understood that this is chiefly dependent upon the range of temperature in the cylinders. While there is economy in the increased expansion that can be obtained from the higher pressures, there is a loss from condensation from the enlarged range of temperatures. If a lower pressure is used with the same number of expansions the range of temperature is reduced, for ex-

ample, in a triple-expansion engine carrying 185 lbs. of steam by gauge, and another carrying 125 lbs., the temperatures and ranges are as follows:

TRIPLE-EXPANSION ENGINE.

Gauge Pressure.	Temp. of high-pres. inlet steam.	Temp. of low-pres. exhaust steam.	Total Range.	Range in each cylinder.
185 lbs.	382°	142°	240°	80°
125 lbs.	353°	142°	211°	70°

While there is great economy to be realized from the earlier stages of expansion there is much less from the later stages; for example, the value of a pound of steam when following a piston full-stroke being: 1, that for four expansions or a quarter cut-off is 2.386 and that for one-tenth cut-off is 3.303. Diffs. 2.386 and .917. By the use of 125 lbs. gauge-pressure there are in general 20 expansions, and by the use of 185 lbs. gauge-pressure 28 expansions are available, and the relative values of a pound of steam in the two cases are 2.99 and 4.33 an important gain of 8½ per cent. in economy. How much the condensation would be increased by the greater range of temperature, I am unable to state, as it follows no established law. In the case of the higher pressure the re-heating receiver becomes more efficient. In general, in seeking to economize, there is more to work upon in diminishing condensation because condensation in cylinders is so large, amounting to as much as 50 per cent. of the steam entering the engine in cases. In the Leavitt engine at Lawrence, economical as it was, the condensation amounted to 40 per cent. of the steam entering the cylinders. The use of the jacket in preventing condensation is well established. In many cases the saving from its use has been considerably over 10 per cent., but in some other cases it is much less, as, for instance, in the Pawtucket engine, it was 2 to 3 per cent. Its action is somewhat mysterious, and it cannot be predicted in any case what the saving will be. It is undoubtedly quite essential in the use of the higher pressures.

We have so far confined our attention to the steam-end of the engine, but there is some opportunity to economize at the pump-end. The amount of power in pumping-engines absorbed by friction of machinery and water is in general 8 or 9 per cent., but it has occasionally been as little as 5 per cent., and in the case of the Worthington high-duty engine at Lowell, was found to be only 2.8 per cent. All that can be done to minimize this friction is to send as little work from the steam-end to the pump-end through intermediate machinery as possible, and in this respect a direct-acting pump will probably always lead, although it may be questionable whether the compensating apparatus in the high-duty direct-acting engine may not absorb as much power as the connections and shaft in the fly-wheel engine. Considering the small total friction of the Pawtucket engine, and of the Newton engine in the first test, and of several direct-acting engines, this point may well be raised. Other points to be attended to are a reduction of the suction-lift so that the

pump will promptly and w ll fill, ample suction and discharge-valve areas, ample passages, and easy turns to assist in diminishing friction. Reduction of suction-lift is best effected by vertical pumping-engines. Experience indicates that if the areas through valves and water-passages are sufficient to give a water velocity of 250 ft. per minute or less they are ample. The water through the valves should be carefully guided and not too abruptly deflected. Efforts should be made to reduce shocks in pumps, for when they exist, more or less energy is wasted. This can be accomplished by small lift, and quick-seating valves, but the most perfect means of accomplishing this is by the mechanically-closed valves devised by Prof. Riedler of Berlin. This consists of an apparatus which allows the valves to lift by the water-pressure, but closes them by mechanical means before a return-current has time to form. It is said that by this means pumps can be run at almost any speed without shock. It is hoped that within a year the new Leavitt engine at the Boston Water Works will furnish us with an object lesson in this respect.

I do not wish to imply that the ordinary multiple automatic valve-pump cannot be run fast. The Pawtucket pumping-engine shows that it can with success for years, and there is a fly-wheel pumping-engine at Toronto designed by the George F. Blake M'g. Co. that has for several years been running from 60 to 80 revolutions per minute. It consists of a Brown cross-compound engine with the piston-rods passing through the back cylinder-heads into Blake pumps with large valve-area. The pumps receive water under pressure, and they work with perfect quiet. It is a significant fact in this connection that many pumping-engines which have been speeded up have run best at the highest speeds, especially if they have low-suction lift and a large valve-area. This is undoubtedly due to the high velocity of the water and the proportionate inability to form a return-current by a reversal of the plunger-movement, and thus a slower seating of the suction-valves and resultant reduction of shock. It is conceivable that a pump might run so fast that the current of the water would move forward so rapidly that reversal would not occur, and that there could not be a shock. In that case the suction-valves would be slow in seating and seat by the pressure of the springs upon them.

The plunger-speed of pumping-engines is often, and in fact generally, limited to a certain number of feet per minute, without regard to the number of strokes made by the engine. There is wide-spread misapprehension on this point. The requirement mentioned is imposed in order to diminish shocks, but as the shock occurs at the instant of the reversal of the plunger it is evident that a limitation of reversals should be made. If the reversal has been made, and the shock has occurred, it is evident that the water can be moved with unlimited speed and safety. Engines are often built to make a certain number of revolutions per minute, and are so designed that the plungers have a shorter stroke than the steam-pistons in order to diminish the plunger speed. Such an arrangement can accomplish nothing, for the same amount of water must be displaced at each stroke whether the pump-stroke is long or short, necessitating the same amount of valve-area, the same acceleration and retardation of water, and often inconvenience in construc-

tion. With the shorter stroke the plunger diameter must be increased and in many designs this requires an undesirable diameter of pump in order to secure sufficient valve-area.

The superintendent of water works is often required to select between vertical and horizontal pumping engines. I trust that the time will come when no horizontal pumping engines will be made for they are likely to be a source of great expense in repairs in consequence of wearing cylinders and pumps from the friction caused by the weight of the moving parts. In some cases pistons act like planing machines on the cylinders, and leakage of steam and reduction of duty may result. The horizontal engine also requires more cylinder oil than the vertical, and the friction of the machine is greater in the former. It is notorious that the vertical engine for any service is more durable, reliable and economical than the horizontal.

Having considered pumping engines from various points of view, I wish to consider methods of testing. Within a few years a movement toward a rational system of testing pumping engines has occurred, which culminated in the appointment of a committee by the American Society of Mechanical Engineers to devise and report upon a standard method of conducting and reporting such tests. For a number of years it has been common to separate the engine from the boiler by specifying duty per a certain number of pounds of steam used by the engine, as 1000 lbs. As the engine does its work in virtue of heat carried to it, it is obviously better to specify duty in terms of a certain number of units of heats used by it and its necessary auxiliaries, such as re-heaters, jackets and feed pumps. The committee referred to reported in favor of this plan and recommended the use of 1,000,000 British Heat units, or in other words that the duty shall be the number of foot pounds of work done by the pump per 1,000,000 heat units absorbed by the engine. I propose to explain this in detail. When steam of a certain pressure, and therefore temperature, passes the throttle valve into the engine, each pound possesses a certain number of heat units, and knowing the number of pounds entering the engine by weighing the feed water it is an easy matter to compute the total amount of heat units that enter the engine in a given time. This steam passes out of the engine partly as steam and partly as water, at a temperature lower than that at which it entered. The engine has therefore used a certain number of heat units in doing its work. The temperature at the end of the process is called the temperature of rejection, and is practically the temperature of the feed water as it leaves the engine or any feed water heater with which the engine is provided, for the cycle takes place between the engine and boiler. If there are jacket and re-heater drains, their amounts and temperatures must be considered if it be practicable to return them to the boiler. It is obvious from this, that the hotter the feed water the less heat the engine uses, and the higher the duty will be. If independent feed pumps are used they must be considered a part of the engine, the steam used by them counted, and the temperature of the boiler feed if raised by these pumps must be taken for the temperature of rejection. If cold water is used for feed its temperature is the temperature of rejection. In such a test the initial pressure should be taken close to the engine so that the engine shall

not suffer from the condensation and wire drawing which may come from a long pipe, for which it is in no way responsible, and the temperature of rejection shall be taken as near the engine as possible so that it shall not suffer from a fall on account of a long feed pipe for which it is in no way responsible.

Now in regard to the foot pounds of work done by the pump end, this should be determined by multiplying the pressure against which the plunger acts including suction lift by its area of cross section and by the distance through which it moves. It will be observed that this method takes no account of the water pumped, for this can be determined by weir measurement or otherwise, and the contractor should be held as responsible for the capacity of the pump as for the duty.

The quality of the steam near the engine should be determined in order to accurately compute the amount of heat passing into the engine.

The propriety of leaving the boiler out is evident. It may be a poor evaporator, a bad primer, it may have good or bad coal, it may be fired well or badly, or it may be dirty, and for any of these the engine is not responsible. In order to protect the purchaser the boiler should be put in under a guarantee to evaporate so much water, when reduced to the equivalent of feed at 212 degrees and evaporation at that temperature, per pound of combustible consumed.

In this connection I wish to refer to the need of a standard coal for testing boilers, and I think it would be well for this Association to officially recommend the use of George's Creek Cumberland in lump form. This coal is recommended because it is easily procured, is good, and suffers less from exposure and transportation than some others. The lump form is recommended because it is nearer a standard state than fine coal, and is therefore a more definite thing. The boiler should not be held responsible for the incidents of transportation and exposure.

The duty of pumping engines is often greater on trials than in later service, but there are some exceptions, the Lynn and Lawrence engines being examples. If the coal used for heating and other services is deducted I should generally expect an increase of duty, for if the engine and boilers are not neglected all parts must work better and they are likely to be treated by more intelligence with increase of experience.

Finally I wish to draw your attention to the means of producing economy that are left to us. We must look to the steam end of our pumping engine for further improvement, as pump resistances are near a minimum at present. As before hinted the greates field is in preventing cylinder condensation, and while the triple expansion engine has done much when intelligently designed, it would seem that the quadruple engine is justifiable where coal is not cheap, and this with pressures easily and safely carried.

It would seem that the use of super heated steam offers the most promising field for the future in the prevention of condensation. In the past a durable super-heater has not been produced, but at present I am of the opinion that it can be. The next difficulty is to furnish sufficiently high temperature waste gases for super heating from the boiler without injuring the boiler per-

formance so as to counterbalance the gain from super heating. Recent experiments that I have made with boilers of the locomotive type burning from 16 lbs. to 70 lbs. of coal per square foot of grate per hour show plainly that evaporations of over 13 lbs. of water from and at 212 degrees per pound of combustible can be obtained when gases are escaping at 600° F. This is sufficient for considerable super heating, and such a boiler performance can be obtained with induced artificial draft.

The remainder of the field for economy is chiefly to utilize all waste heat from engine and boiler for heating feed water.

In conclusion I predict that the most economical steam plant of the future will be designed as follows :

The boiler will be of the locomotive type having a ratio of heating to grate surface of 75 or 80 to 1, working with over 200 lbs. of steam, having artificial draft and burning 30 or 40 pounds of coal per square foot of grate per hour. This type of boiler is selected because it is the most economical of all boilers, either when forced or not, will stand the highest pressures, extreme forcing, and general abuse without harm for many years. It is the pioneer of high pressures throughout the world, and its success under the most trying conditions, shows it to be perfectly safe.

The engine used will be a moderately fast running vertical quadruple expansion, furnished with steam, super-heated by the waste gases of the boiler. The cylinders will be steam jacketed, and the initial steam in the high pressure cylinder may be wire drawn considerably below the boiler pressure. There will be re-heaters between the cylinders, the condensation from the working steam side of which will be passed through evaporators in the smoke flue of the boiler and returned to the most advantageous point of the engine.

The live steam should not evaporate any of this condensation, on account of the great amount of heat required, but should merely prevent condensation. The condensation from the live steam side of the re-heater should be returned to the boiler. There will be a feed water heater in the low pressure exhaust pipe, and this water will have added to it the rejected heat of the auxiliary engines if there are any, and will then pass through an economizer in the flue beyond the super-heater and evaporator on its way to the boiler. The jacket condensation will pass to the boiler independently. The smoke box end of the boilers will be near the engine in order to diminish the dissipation of the super-heat of the steam which occurs very readily.

In the case of pumping engines the pumps will have a large valve area with many small automatic valves or with few large automatic lifting and mechanically closing valves.

TOPICAL DISCUSSION.

June 15, 1893.

The Filling of Service Pipes by Sediment or Tuberculation.

The President. I suppose it is well understood that the ideal service pipe has not yet been invented, whether you use lead or wrought-iron or cement-lined or enamelled pipe or any other kind. There is some objection to every one of them, through different waters have different effects on the pipe, and we have had different experiences, and it seems to me we might derive some benefit from an interchange of our experiences in this direction. I will call upon Mr. Noyes to tell us something about the service pipes in Newton.

Mr. Noyes. Our works were constructed in 1876, and the engineer in charge made as careful investigation as he could within the limited time, as to how the different pipes would act in water which is supplied to the city. The tests showed that the tar-coated wrought iron pipe gave a good result, and it was almost universally used for the first two years; but it was found in practice that it filled up very rapidly, and although there are some of the pipe that have been in service up to the present time, yet they are almost entirely filled up. They have used the various classes of enamelled wrought-iron pipe, but they gave unsatisfactory results. They are using now lead pipe altogether or the galvanized iron pipe. A limited amount of galvanized iron pipe has been in use since the work was constructed, and it shows little or no filling up. The superintendent who has charge of the maintenance and becomes conversant with any services which may be cut out, tells me that he has had no case of either rust or filling up with galvanized iron pipe; so that all the services that are put in now are either lead or galvanized iron at the election of the consumer.

The President. Does any one present know of any cases in which lead pipe has filled up.

Mr. Fuller. I had some samples of pipe at one of the meetings last winter, taken from the Wellesley water works, and, as Mr. Noyes has said, the tar-coated wrought-iron pipe has given very poor results in six or seven years, it is practically good for nothing, and is almost entirely filled with rust or corrosion. We put in a few galvanized services, and one of those was cut out a while ago to insert a meter, and that also showed signs of rust and corrosion. For the last four or five years we have used the cement-lined wrought-iron, and except for a little trouble occasionally from the cement coming off we have had no trouble with it whatever. It seems to me that either lead or the cement-lined wrought-iron is the best service pipe we have. I do not know how satisfactory the iron lead-lined pipe would be found, although it seems as though that might prove to be a good pipe, but the plain wrought-iron pipe is evidently not suited for service pipe work. I know the delivering capacity of a pipe in my own house, which was put in about 1886, is not more than about a seventh now, of what it was when it was put in. That is tarred iron pipe.

THE PRESIDENT. We use in Taunton a cement-lined wrought iron pipe, and we have a good many complaints of poor service and frequently have to clean out the pipe, and sometimes put down new pipe. I find in looking over the records that as a rule those services have been in for ten or a dozen years, but sometimes we have had trouble with services that have not been in more than a year or two. In most cases the trouble has been either at the corporation cock, the service cock or at the couplings. The couplings were lined by a thimble of about three-quarters inch bore which was put in the centre of what had been an inch pipe, this thimble being made of composition, nickel plated, and then the space between that and the iron coupling packed in with solder; but even then the cement would get broken off the pipe a little, and there was some contact between the iron and the thimble, so that there was a galvanic action, and I have seen those couplings so obstructed that there wasn't a space as big as my little finger for the passage of the water.

And there is something else besides tuberculation and sedimentation that sometimes occurs. We had a complaint one day of a service being suddenly stopped. In most cases the stoppage is gradual, but in this case I have in mind it was sudden. When disconnection was made at the goose-neck, the 18 inches of lead, an eel was found to have stopped up the whole length of that lead, his head just pushing into the union, and at the time he was found he was alive. On another occasion there was a similar sudden stopping, and in that case the eel had his head just stuck at the corporation. The foreman was sent to look after it, and he said he couldn't get it out. Said I, "You must do it; it won't do to have him die there;" and finally he got him out. In both these cases the eel was a foot long and as big around as the base of my thumb. He could not have got in through the screens or gone through the valves of the pump unless he was very small and then grown. I suppose these eels are in the pipes travelling around and having a good time, and once in a while they get into a place where they give us this trouble.

The character of the water has something to do with the filling up of the pipe, as well as the character of the pipe. It is well understood that water that is imperfectly filtered, especially when the water contains iron, is susceptible to the growth of an organization called crenothrex, and that is bound to fill up the pipes. I have strong hopes that when we get through using Taunton river water, or use it with something else, we shall not have so much trouble from tuberculation and sedimentation in the service pipes.

MR. BROWN. I remember on one occasion the water stopped in a 2-inch pipe, and in the nipple from the tap in an 8-inch main we found an eel that completely filled it. He had got his head through and stuck there. He measured three feet six inches long by six inches in circumferance. As to how he got there I can't say, and it is the only instance of the kind I have known on the works. With regard to service pipe, I will say we use wrought-iron cement-lined. We have eight or nine hundred services which have been in twenty years, and perhaps a dozen a year bother us by filling up. The trouble is mostly with the Ts and elbows. We have very little trouble with the couplings, and they stand freezing better than anything else we have.

Out of perhaps three or four hundred services frozen last winter but twenty-five were cement-lined.

MR. BEALS. I recollect one inch and a half pipe we found entirely filled. It was an enamelled iron pipe, the only one of the kind we had in, and upon examination we found that the enamel had flaked from the pipe and gone forward under the pressure of the water and finally filled the pipe. It was a service which was using a great deal of water. Most of our services are cement lined pipe. At times, when the lining was not perfect, where the two joints are screwed together, and where the water reaches the iron, we find a little deposit of rust around the coupling. But during our eight years of experience we have never yet had to take out a service pipe because of a deposit or incrustation stopping the pipe. In the case of this enamel pipe spoken of, we we took it out, and as the customer was a large one we ran a special 4-inch main clear to the cellar of his place. He has a 2-inch meter, and is using some 50,000 gallons a day.

MR. CHASE. The liquid which we supply our consumers is a dark brown surface water, common to the coast of the Southern States and, coming from the cypress swamps, has quite a large amount of tanic acid in it, as I am informed, which has a very corrosive effect upon iron. The first pipe we used for services was the enamel pipe. After a year or two we found it was not giving satisfaction, showed very pronounced signs of filling up, and we changed to galvanized iron, and have used that for the last ten years with very gratifying success. The only vulnerable points are at the fresh cut ends. I have seen ordinary wrought iron pipe three-quarters of an inch in diameter, practically filled up in two or three years by tuberculation and sedimentation. We found in a short time that the corporation stops we used did not project far enough through the shell of the iron pipe, and that a sort of excrescence or tubercle was formed over that, entirely stopping up the tap. We now use a corporation which extends through the pipe at least a half an inch, and we have had no trouble. It has become necessary to provide means for reaming out the stops which fill up, and I suppose we have half a dozen every year, increasing in number; and for that we use a drill running through a stuffing box which is screwed on the corporation. Very much the same device as used for tapping the cement or "mud" pipes, as our friend Walker calls them. We occasionally have a stoppage by a fish getting his head in, but all we do then is to punch him through and let him go on and say nothing about it.

OBITUARY.

CHARLES W. S. SEYMOUR—Superintendent Water Works, Hingham, Mass. Died October 16th, 1893. Aged 54 years, 1 month. Joined this Association April 21st, 1885.

WILLIAM DIXON—Formerly Superintendent Mt. Pleasant, Mich. Born at Manchester, England. Died September 12th, 1893. Aged 44 years, 7 months. Joined this Association June 16th, 1886.

DR. CHARLES F. CREHORE—Member of the Newton Water Board from 1880 to 1888 and was largely instrumental in procuring the improved system of water-works for the City of Newton. Born at Newton Lower Falls. Died November 7th, 1893. Aged 65 years, 3 months Joined this Association April 21st, 1885.

INDEX TO ADVERTISEMENTS.

RUBBER GOODS. PAGE.

Boston Belting Co 22

LEAD AND LEAD PIPE.

Boston Lead Manufacturing Co 11
Chadwick Lead Works 10
Tatham and Brothers 9

CAST-IRON PIPE AND SPECIALS.

McNeal Pipe and Foundry Co 18
Chas. Millar & Son 16
Builders' Iron Foundry 16
Emaus Pipe Foundry 19
Jackson & Woodin Manufacturing Co 16
M. J. Drummond 17
R. D. Wood & Co 15
Warren Foundry and Machine Co 17

GATES, VALVES AND HYDRANTS.

Crosby Steam Gage and Valve Co 12
Chapman Valve Manufacturing Co 13
Peet Valve Co 14
Ludlow Valve Mfg. Co 12
The Fairbanks Co 13
Ross Valve Co 16

STEAM PUMPS.

Deane Steam Pump Co 20

BRASS GOODS AND TAPPING MACHINES.

Peck Bros. & Co 9
Walworth Manufacturing Co 8
Anthony P. Smith, (Patentee) 7

PACKING.

Gould Packing Co 21
Randolph Brandt 21
American Supply Co 11

METERS.

Henry R. Worthington 3
Hersey Manufacturing Co 4
National Meter Co 2
Thomson Meter Co 5
Union Water Meter Co 6
Builders Iron Foundry 7

CEMENT.

Lawrence Cement Co 25

TOOLS.

Perrin Seamans & Co 19

BRIDGES AND STAND PIPES.

Berlin Iron Bridge Co 23
E. Hodge & Co 24

DRAWING TOOLS, ETC.

Frost & Adams 25

120,000

CROWN,

NASH,

GEM,

and

EMPIRE

WATER METERS

Made and sold to date.

NATIONAL METER CO.,

287 Broadway, New York.

159 Franklin St., Boston.

AUGUST, 1893.

s. d. m. j.

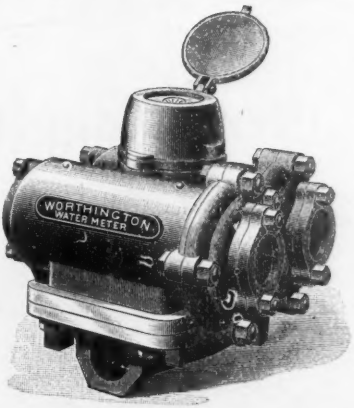
THE WORTHINGTON WATER METER

Used by the Water Companies of the United States and Canada for over FORTY YEARS and pronounced by them

"UNEQUALLED FOR ACCURACY AND DURABILITY."

All parts constructed of Iron and Brass.

The Counter movement is not exposed to the action of the Water.



Positive in operation.

Simple in construction.

Accurate in Registration.

Hot Water Meters, Oil Meters, Meters for Naphtha, Alkaline Liquors and Special Services.

For New Catalogue and Prices call on or address

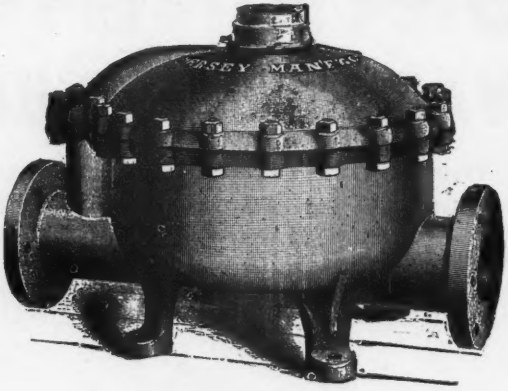
HENRY R. WORTHINGTON

86 and 88 Liberty Street, New York.

70 Kilby Street, Boston. *607 Arch Street, Philadelphia.*
93 and 95 Lake St., Chicago. *404 and 406 Walnut St., St. Louis*

s. d. m. j.

WATER METERS



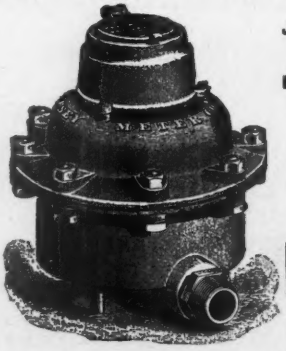
—AND—

Water Works Appliances.

We manufacture on a LARGE SCALE and Guarantee our work.

Our goods are scattered throughout the WORLD and have reached nearly every department in the United States where meters are used.

We have established Agencies for the convenience of distant customers as follows:



CHICAGO:
Jas. B. Clow & Son.

ST. LOUIS:
N. O. Nelson Mfg. Co.

NEW ORLEANS:
New Orleans Railway & Mill Supply Co. (Ltd.)

SAN FRANCISCO.
Dunham, Carrigan & Hayden Co.

We should be pleased to furnish you our Price List and Illustrated Catalogue on application.

Hersey Manufacturing Co.
South Boston, Mass.

s. d. m. j.

THOMSON METER CO.,

SOLE OWNER LAMBERT-THOMSON METER PATENTS.

THE LARGEST EXCLUSIVE

WATER METER MANUFACTURERS

IN THE WORLD.

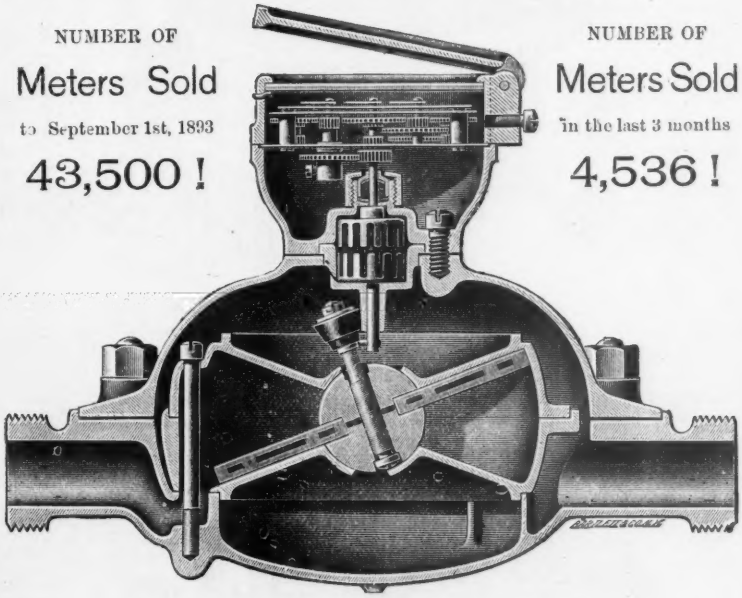
79-83 WASHINGTON ST., BROOKLYN, N. Y.

NUMBER OF

Meters Sold

to September 1st, 1893

43,500 !



NUMBER OF

Meters Sold

in the last 3 months

4,536 !

SECTION OF THE $\frac{3}{4}$ INCH SIZE BEE METER—HALF SIZE.

NO METAL OTHER THAN

BRONZE, COMPOSITION, BRASS AND GERMAN SILVER

is used in the manufacture of this meter.

s.d.m.j.

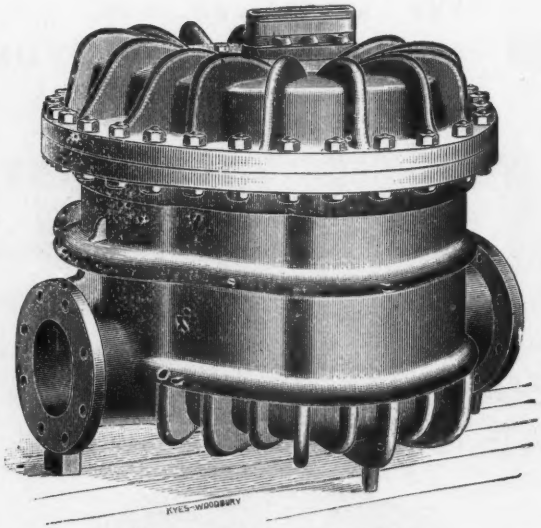
UNION ✣ WATER ✣ METER ✣ CO.,

WORCESTER, MASS.

ESTABLISHED IN 1868.

Man'f'rs of the only positive

MEASURING 12-in. METERS.



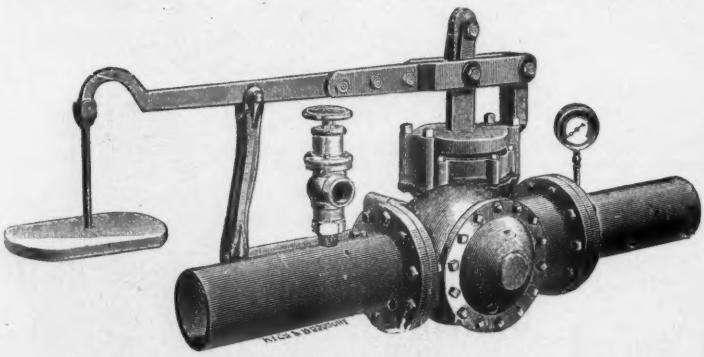
Manufacturers of the **METER** most extensively used on Hydraulic Elevators, Locomotive Stand Pipes, &c.

Extra Heavy Rotary Piston Meter.

ROTARY AND RECIPROCATING PISTON

WATER METERS.

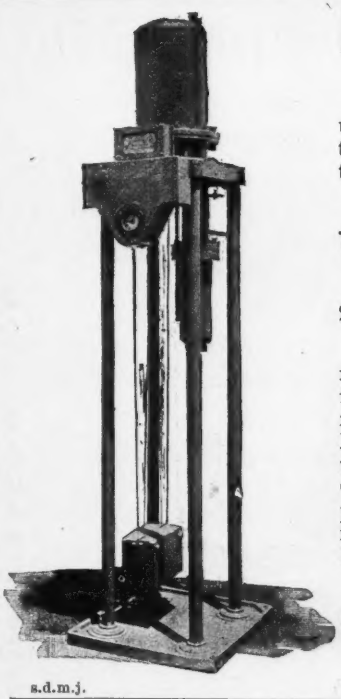
Sizes 5-8 inch to 12 inches. Send for Catalogue, etc.



Water Pressure Regulator.

The only positive Automatic Water Pressure Regulator in the market. We have never had a failure.

s.d.m.j. Write for Lithotype, etc.



s.d.m.j.

LARGE quantities of Water measured easily, regularly and accurately.

A 36-INCH VENTURI METER,

used in the extreme southeast corner of the grounds, near the Power House, on the

MAIN WATER SUPPLY
OF THE
WORLD'S COLUMBIAN EXPOSITION

Amount of water measured daily, about 20,000,000 gallons.

A 6-Inch Venturi Meter

is used to measure the drinking water as it passes to the grounds from the cooling machine at the pavilion of the Waukesha Hygeia Mineral Springs Company, near the exhibit of the Pennsylvania Railroad Company, at the south end of the Transportation Building, between the Sixty-fourth Street entrance and the Mines and Mining Building.

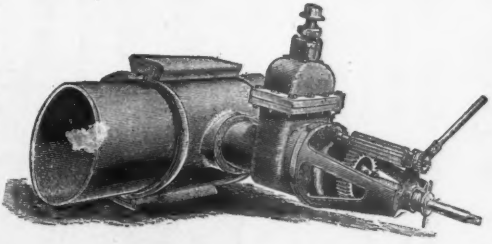
☞ Description on application.

Builders' Iron Foundry.
PROVIDENCE, R. I.

CONNECTING BRANCH SLEEVE AND TAPPING APPARATUS.

What Every Water Department Has Been Looking For.

A tapping apparatus to make large connections without shutting off the water or diminishing the pressure. This is now an accomplished fact, no experiment. It has passed the experimental stage, having been used by the Water Departments of several cities for the past years with entire success, and with a great saving to the departments, connections having been made 2, 3, 4, 6, 8, 10, 12, 14, 16 and 20 ins. with mains from sizes 4 to 48 ins. Connections can be made up to the full size of the main, as a 6-in connection with a 6-in. main, 10-in. connection with a 10-in. main, and so on to any size required.



In making connections by this method the circular piece cut from the main is removed by the tapping apparatus, and is not allowed to fall into the main. By this method it is not necessary to use special castings in laying mains; saves trouble and expense of cutting the pipe to place special castings in their proper positions; either double or single connections can be made with the same sleeve, and at any desired place on the main; connections can be made without the gate, if desired. Fire Hydrants can be located and set up on any line of mains already in use, thus enabling cities which have large mains and no hydrants connected with them to do so without any risk.

Connections for automatic sprinklers, hydraulic elevators, water motors and for factories can now be made by this method and apparatus as easily as ¾-in. or 1-in. taps.

FOR FURTHER INFORMATION ADDRESS,

ANTHONY P. SMITH, (Patentee),

Room No. 921 Prudential Building, Bank and Broad Sts.,

j.s.d.m. **NEWARK, N. J.**

WALWORTH MANUFACTURING CO.,

BOSTON, MASS.

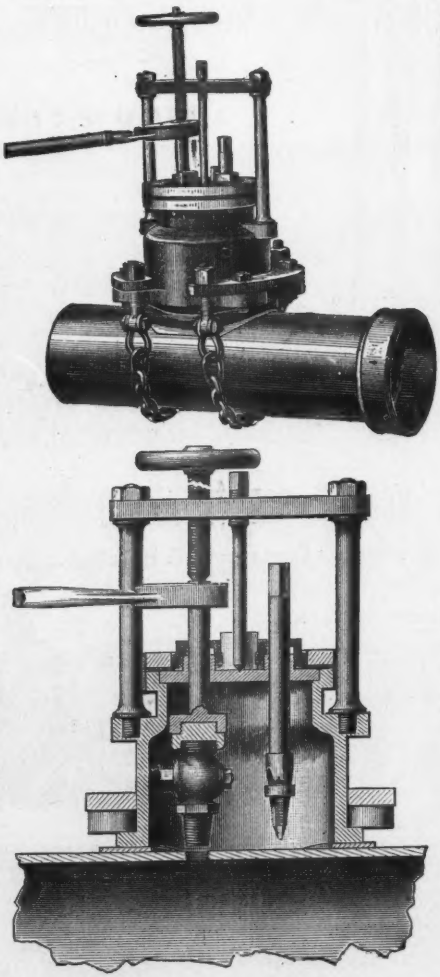
New York Office, 54 Gold Street.

THE HALL TAPPING MACHINE (Patented.)

WATER WORKS SUPPLIES.

Wrought and Cast Iron Pipe and Fittings. Brass Work of all kinds. Water, Steam and Gas Fitters' Tools and Supplies.

Extension Shut-off Boxes. Straight-way and Hydrant Valves a Specialty. Miller's Rachet Pipe-Cutting and Threading Tools, &c., &c.



Water Works Engineers, who have tested the Machine, claim that it has no equal for efficiency and durability, and furnish strong testimonials. If you have not already done so, will you not investigate its merits and send for Descriptive Circular and Price List, and especially note *prices of duplicate parts*, and also what we furnish with a Machine.

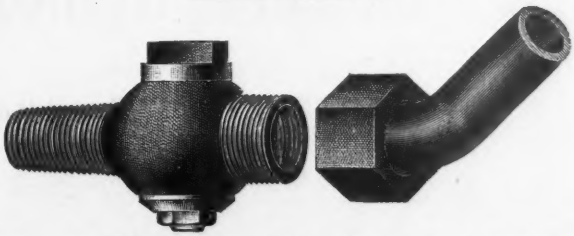
For tapping main pipes under pressure, ***Simplest and Best. Three Machines in One.*** Body made of Brass, Trimmings of Wrought Iron and Steel.

ALL GOODS GUARANTEED FIRST-CLASS.

s.d.m.j.

PECK BROS. & CO.,

MANUFACTURERS OF



BRASS GOODS OF EVERY DESCRIPTION,

—FOR—

WATER, GAS AND STEAM.

We make a specialty of **Tested** and first-class goods in Brass for Water Companies.

127 Chestnut Street, New Haven, Conn.

47 Cliff St., New York. **259 Wabash Ave., Chicago, Ill.**

65 and 67 Oliver St., Boston, Mass.

d.m.j.s.

TATHAM & BROTHERS,

STANDARD LEAD PIPE,

TIN LINED LEAD PIPE,

BLOCK TIN PIPE, SHEET LEAD, BAR LEAD,

LEAD TRAPS, DROP AND BUCK SHOT,

BLOCK TIN, PIG LEAD, SOLDER.

82 Beekman St., - - - NEW YORK.

d.m.j.s.

CHADWICK LEAD WORKS,

Nos. 176, 178, 180, 182 and 184 HIGH STREET (Fort Hill Square)

BOSTON, MASS.,

——MANUFACTURERS OF AND DEALERS IN——

LEAD PIPE, TIN PIPE, SHEET LEAD,

SHEET TIN, RIBBON AND TAPE LEAD,

WHITE LEAD, Dry and in Oil, RED LEAD,

LITHARGE, COPPER AND IRON PUMPS,

SOLDER, **PIG LEAD,** PIG TIN, Etc., Etc.

☞ **Lead encasing Electric Cables and Wires a Specialty.**

PROPRIETORS OF

THE FOREST RIVER LEAD WORKS,

SALEM, MASS.

Correspondence with Water Works solicited.

s.d.mj.

SAMUEL LITTLE, President. WILLIAM J. BRIDE, Treasurer.

Boston Lead Manufacturing Company,

Corner of Congress and Franklin Streets,

162 Congress St. BOSTON. 180 and 182 Franklin St.

MANUFACTURERS OF

WHITE LEAD,

Red Lead and Litharge Patent Tin-Lined Lead Pipe,

PURE BLOCK TIN PIPE.

Lead Pipe and Sheet Lead.

ALSO DEALERS IN

Pig Lead, Pig Tin, Solder, Pumps, Etc.

s.d.m j.

AMERICAN SUPPLY COMPANY,

READING, PA.

Manufacturers of Plain and Tarred Packing

For Caulking WATER, GAS and SEWER PIPE.

Also Plumbers Spun Oakum.

Italian and American Hemp and Flax Packing; Cotton Waste; Special Rope for Electric Light Companies.

And in fact Rope, Cordage and Twines of every description.

AMERICAN SUPPLY CO.

P. O. Box No. 247, Reading, Pa.

Eastern Agency, H. B. Winship, No. 185 Devonshire St., Boston, Mass.

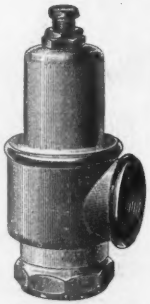
s. d. m. j.

Crosby Steam Gage AND Valve Co.

SOLE PROPRIETORS AND MANUFACTURERS OF

CROSBY POP SAFETY VALVES and WATER RELIEF VALVES

CROSBY Improved Steam Gages,
CROSBY Steam Engine Indicators.



WATER RELIEF VALVE.

BOSWORTH Feed Water Regulator and Pressure Regulator.

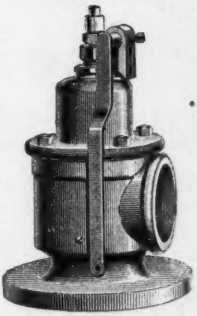
Patent Gage Testing Apparatus.

SOLE AGENTS FOR

Clark's Linen Fire Hose and Couplings.

DEALERS IN

Engine, Boiler, Mill and Fire Department Supplies.

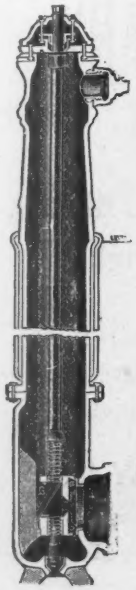


SAFETY VALVE.

Office and Works, - BOSTON, MASS.

Branches- New York, Chicago and London, Eng.

s.d.mj.



THE LUDLOW VALVE MFG. CO.,

MANUFACTURERS OF

Valves and Fire Hydrants.

This hydrant is anti-freezing, because when the drainage is good no water is left in it to freeze. The drip is directly in the bottom of the hydrant and drains perfectly. It is protected by its valve, which never leaves its socket and cannot be clogged.

DOUBLE AND SINGLE GATE

Valves.

—ALSO—

Check Valves,

Foot Valves,

Fire Hydrants,

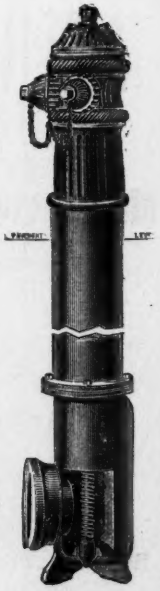
Yard,

Wash

and

Flush

HYDRANTS



Send for Circulars.

Office and Works: 938 to 954 River St., and 67 to 83 Vail Ave., Troy, N. Y.

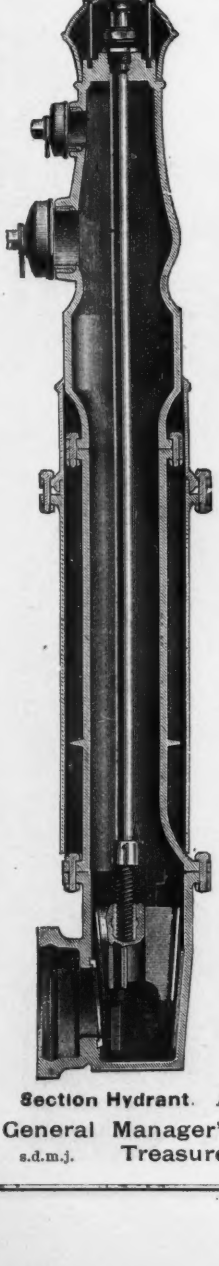
s.d.m.j

CHAPMAN VALVE MANUFACTURING CO.,

—MANUFACTURERS OF—

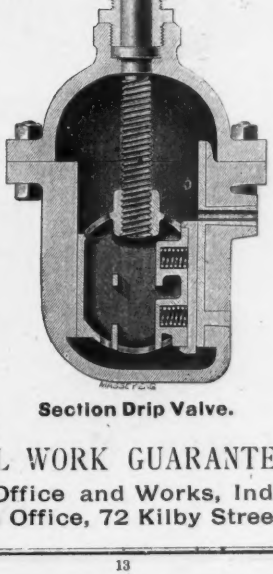
VALVES AND GATES FOR WATER, GAS, STEAM, &C.

GATE FIRE HYDRANTS.

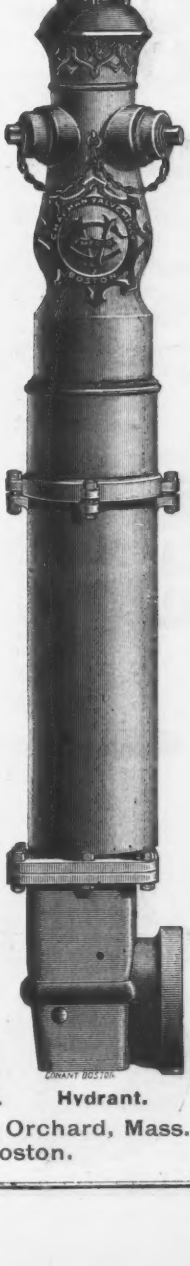


Section Hydrant.

Bell End Water Gate.



Section Drip Valve.



Hydrant.

ALL WORK GUARANTEED.

General Manager's Office and Works, Indian Orchard, Mass.

s.d.m.j. Treasurer's Office, 72 Kilby Street, Boston.

PEET VALVE CO.,

MANUFACTURERS OF THE

Genuine Double Gate Peet Valves,

FOR STEAM, WATER, GAS, Etc.

Special Valves for all purposes Made to Order.

Peet Valve Co.,

163 Albany St.,

Boston, Mass.

s.d.m.j.

R. D. Wood & Co.

Engineers,

Iron Founders,

and Machinists.

Office: 400 Chestnut Street, Philadelphia.

Foundries and Works: {Millville, Florence, Camden,} N. J.

FIRE HYDRANT
With Crane Attachment for Sprinkling Cart.
s.d.m.j.

Constructors

of

Water and Gas Works.

MANUFACTURERS

—OF—

Cast Iron Pipe

TURBINE WHEELS,

Pumping Machinery,

Hydraulic Cranes,

Lifts and Machinery,

Heavy Loam Castings,

"Eddy" Valves,

"Mathews'" Hydrants

C. H. Zehnder, President. Wm. F. Lowry, Secretary and Treasurer.
Fred'k H. Eaton, Vice President, H. F. Glenn, Gen. Manager.

THE JACKSON & WOODIN MFG. CO.,

MANUFACTURERS OF

Cast Iron Water and Gas Pipe,

Special Castings, Lamp Posts, Car Wheels,

Cars, Merchant Iron and

Forgings.

BERWICK, COL. CO., PENNA.

s.d m.j.

UTICA PIPE FOUNDRY CO.

CAST IRON PIPE AND SPECIALS FOR WATER AND GAS.

Flanged Pipe and Fittings, Hydrants, Gates, Pig Lead, etc.

CHAS. MILLAR & SON, Selling Agents, Utica, N. Y.

Manufacturers of Lead Pipe and Plumbers' Materials. Wholesale Eastern Agents

AKRON VITRIFIED SEWER PIPE.

Also Wrought Iron Pipe.

Shipments to any part of the United States at lowest market rates.

m.j.s.d

ESTABLISHED 1856.

Warren Foundry & Machine Co.

WORKS AT PHILLIPSBURG, NEW JERSEY.

Sales Office, 160 Broadway, New York.

Cast Iron, Water and Gas

PIPE,

From 3 to 48 Inches Diameter.

—ALSO—

ALL SIZES OF FLANGED PIPE

—AND—

SPECIAL CASTINGS.

s d.m.j.

M. J. Drummond.

Flange Pipe, Lamp Posts, Stop Valves, Fire Hydrants, and General Foundry Work.

BUILDERS' IRON FOUNDRY

"Globe" Specials.

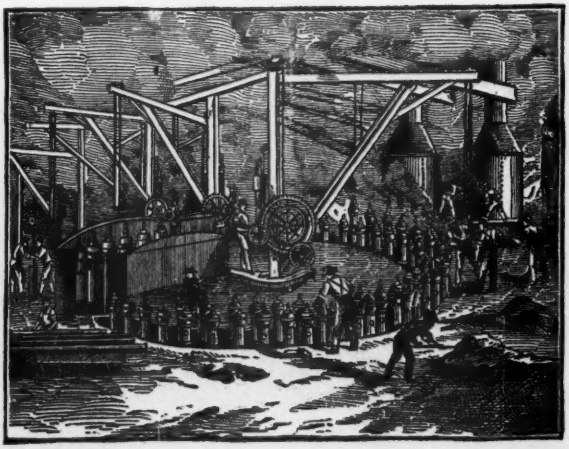
Office, Corbin Building, 192 Broadway, New York.

a.d.m.j.

THE

McNeil Pipe and Foundry Co.,

BURLINGTON, N. J.



CAST IRON PIPES,

FOR WATER AND GAS.

Flange Pipes, General Foundry Work.

s.d.m.j.

GEORGE ORMROD,
Manager and Treas., Emaus, Pa.

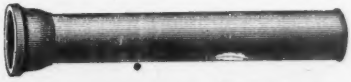
JOHN DONALDSON, President,
136 South Fourth St., Phila., Pa.

EMAUS PIPE FOUNDRY.

DONALDSON IRON CO.,

MANUFACTURERS OF

CAST ⁘ IRON ⁘ PIPE,



FOR WATER AND GAS.

ALSO

SPECIAL ⁘ CASTINGS.

EMAUS, Lehigh Co., Pa.

s.d.m.j

PERRIN, SEAMANS & CO.,

57 Oliver St., BOSTON, MASS.

LEAD FURNACES.

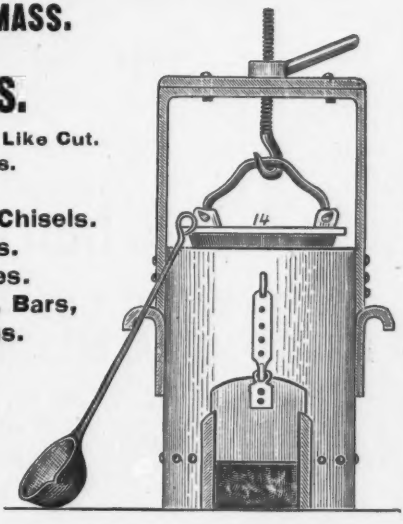
No. 1 for Repairs. No. 2 Like Cut.
No. 3 Mounted on Wheels.

Caulking Hammers and Chisels.
Watkins Pipe Jointers.
Jute Packing. Ladles.
Picks, Shovels, Hammers, Bars,
Rope, Blocks, Lanterns.

Diaphragm and Centrifugal

PUMPS,

and all Construction Tools.

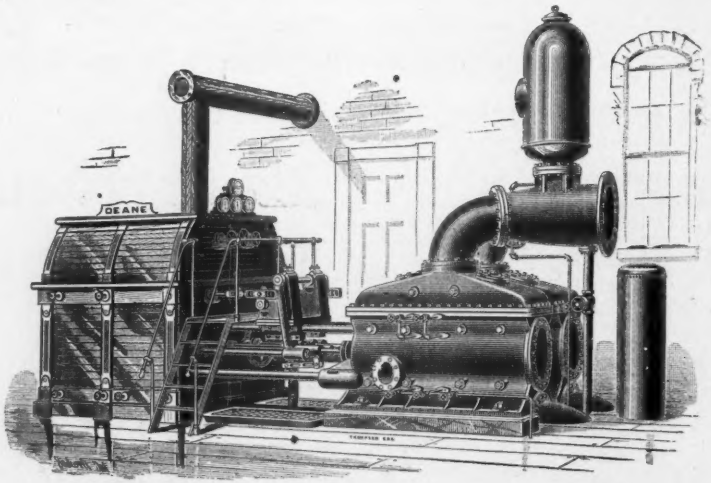


☞ **SEND FOR CATALOGUE** ☜
j.s.d.m.

The Deane,

OF HOLYOKE,

STEAM PUMPS.



Water Works Engines.

Daily Pumping Capacity of Deane Water Works Engines in Service,

Over 325,000,000 Gallons.

For Illustrated Catalogue write

The Deane Steam Pump Co.,

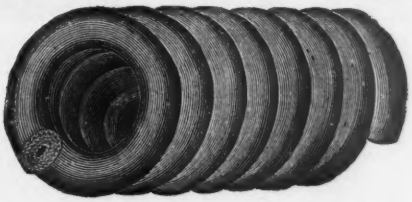
HOLYOKE, MASS.

New York, Boston, Chicago, Philadelphia, St. Louis, Denver. Birmingham, Ala.

t.f.

RANDOLPH BRANDT,

38 Cortlandt St.



NEW YORK.

MANUFACTURERS OF THE

SELDEN PATENT PACKING

(With and without Rubber Core),

For Stuffing-Boxes on Plungers, Piston-Rods, and Valve-Stems.

These packings are made of carefully selected materials, FREE FROM GRIT, and are

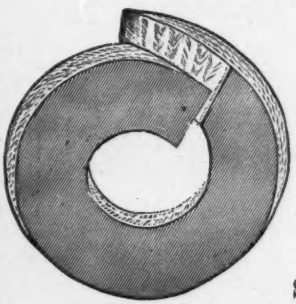
SELF-LUBRICATING AND ELASTIC.

The following are a few of the representative houses who use and recommend the Selden Packing: Knowles Steam Pump Works, Pumping Machinery; George F. Blake Mfg. Co., Pumping Machinery; The Jno. H. McGowan Co., Pumping Machinery; Geo. J. Roberts & Co., Pumping Machinery; The Hooven Owens & Rentschler, Hamilton Corliss Engines; The Ritchie & Dyer Co, Stationary and Portable Engines.

s.d.m.j.

GOULD'S STEAM and WATER PACKING.

PATENTED JUNE 1ST, 1880.



TRADE MARK

THE ORIGINAL RING PACKING

—FOR—

Piston Rods, Valve Stem of Steam Engines, Steam Pumps, and Especially Adapted for Paper and Pulp Mills, Electric Light Plants, Water Works, &c.

Self-Lubricating, Steam and Water Tight.

Less friction than any other known Packing. Never grows hard if directions are followed. Does not corrode the rod. *Every Package fully warranted.*

In ordering, give exact diameter of Stuffing Box and Piston Rod or Valve Stem.

N. B.—This Package will be sent to any address, and if not satisfactory, after a trial of thirty days, can be returned at our expense. None genuine without this trade-mark, and date of patent stamped on wrapper.

All Similar Packings are Imitations and calculated to deceive.

GOULD PACKING CO., 38 Cambridge St., E. Cambridge, Mass.

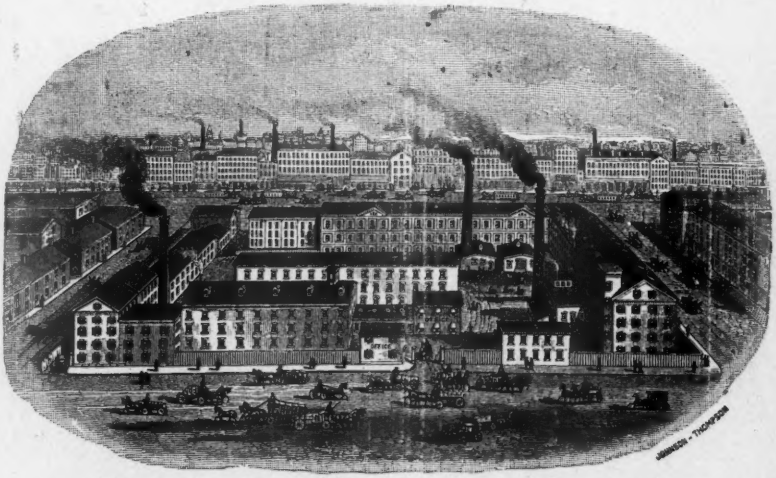
s.d.m.j. A. CHIPMAN, Treas.

BOSTON ✦ BELTING ✦ CO.,

ORIGINAL MANUFACTURERS OF ALL KINDS OF

VULCANIZED INDIA-RUBBER GOODS.

ESTABLISHED 1828.



Factories of the Boston Belting Company, Boston, Mass., U. S. A.

OLDEST AND LARGEST MANUFACTURERS IN THE WORLD

—OF—

RUBBER BELTING.

RUBBER PACKING.

Also Manufacturers of all other articles of VULCANIZED INDIA RUBBER for Mechanical and Manufacturing purposes. RUBBER VALVES of all descriptions for Hydrants, Pumps, Engines, Steamships, etc.

RUBBER HOSE.

WAREROOMS.

256-260 Devonshire St.

BOSTON.

100 Chambers Street,

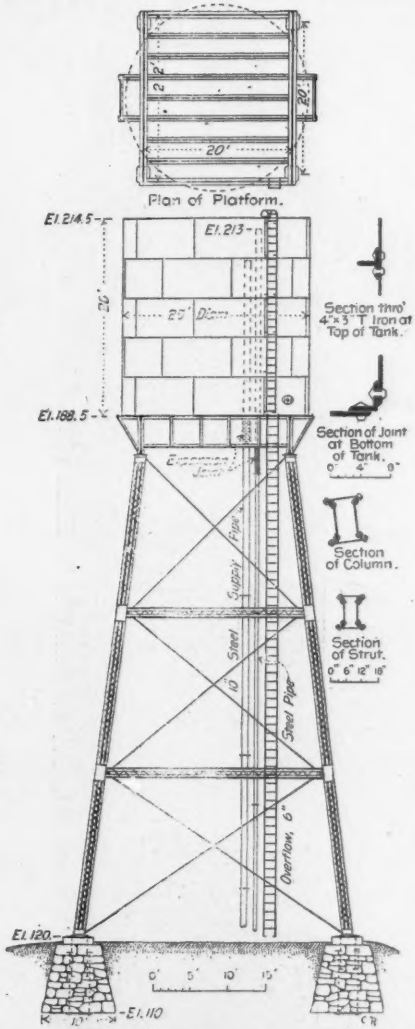
New York.

s.d.m.j.

THE BERLIN IRON BRIDGE CO.

CHAS. M. JARVIS, Pres. and Chf. Engr. *B. K. FIELD, Vice-Pres.*
GEO. H. SAGE, Sec'y. *F. L. WILCOX, Treas.*

This illustration is a Water Tower, designed and built by us for the New London Water Works, at New London, Conn. The Tower is 68½ feet high, surmounted by a tank 25 feet in diameter and 26 feet high, making the full height from foundation to top of tank 94 feet 6 inches. The posts are 36 feet apart at the bottom and 20 feet apart at the top, with suitable braces and tie rods. The other dimensions are given in the illustration.



Engineers, Architects and Builders
IN IRON.

Send for our New Illustrated Catalogue.

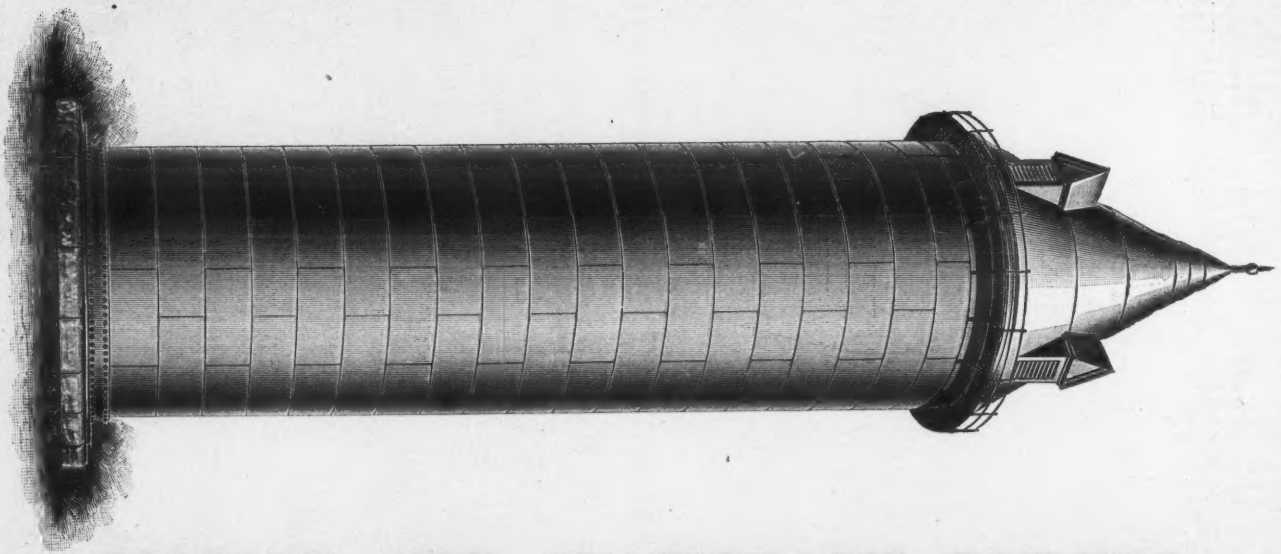
Office and Works, EAST BERLIN, CONN.

s. d. m. j.

E. HODGE & CO.

—BUILDERS OF—

STAND PIPES.



MARINE AND STATIONARY BOILERS.

WORKS: LIVERPOOL STREET, EAST BOSTON, MASS.

BOSTON OFFICE: ROOM 72, MASON BUILDING.

The Edward P. Allis Company,

MILWAUKEE, WIS.,

—BUILDERS OF—

HIGH DUTY PUMPING ENGINES,

Triple Expansion and Compound.

SPECIAL SEWAGE AND DRAINAGE

- - PUMPS. - -

Our Engines have Shown the Highest Duties Ever Recorded:
Milwaukee Engine, 152 MILLION DUTY,
Chicago (three engines,) 148 MILLION DUTY.

WE ARE BUILDERS OF THE

Reynolds' Corliss Engine

d.m.j.s. **FOR ALL POWER PURPOSES.**

March 1894

Table of Contents.

	Page.
Quarterly Meeting	109
Adjourned Meeting	111
Members Present, List of	109, 111
Paper. "Covered Reservoir at Brookline, Mass," by F. F. Forbes, Superintendent, Brookline, Mass.	111, 113
Discussion by Messrs. Brackett, Johnson, Fuller, Noyes, Forbes, FitzGerald, Coffin, Walker and Tidd	123
Paper, "Water Supply of Waltham," by Geo. E. Winslow, Superintendent, Waltham, Mass	118
Paper, "Basin and Well Covering of the Waltham Water Works," by F. F. Johnson, City Engineer, Waltham, Mass.	120
Discussion by Messrs. Brackett. Johnson, Fuller, Noyes, Forbes, FitzGerald, Coffin, Walker and Tidd	123
Paper, "Construction of Reservoir Embankments" by Lucian A. Taylor, Civil Engineer, Boston, Mass	130
Discussion by Messrs. Darling, Taylor, Tidd, Noyes, Brackett and FitzGerald	134
Paper, "The Bursting of the Portland Reservoir," by John R. Freeman, Civil Engineer, Boston, Mass	148
Discussion by Messrs. Fuller, Freeman, Tidd and Brackett	152
Paper, "A Method of Recording the Location of Water Mains," by Geo. A. Kimball, Civil Engineer, Boston, Mass.	157
Discussion by Messrs. Fuller, Harrington and Brackett	157
Obituary—Robert K. Martin.	160
" —Eugene P. LeBaron	160

NOTICE.

An Index to the Transactions, 1883—1885 and the Journal Volumes I—VII is bound with this number.—JUNIOR EDITOR.